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PAGE 32



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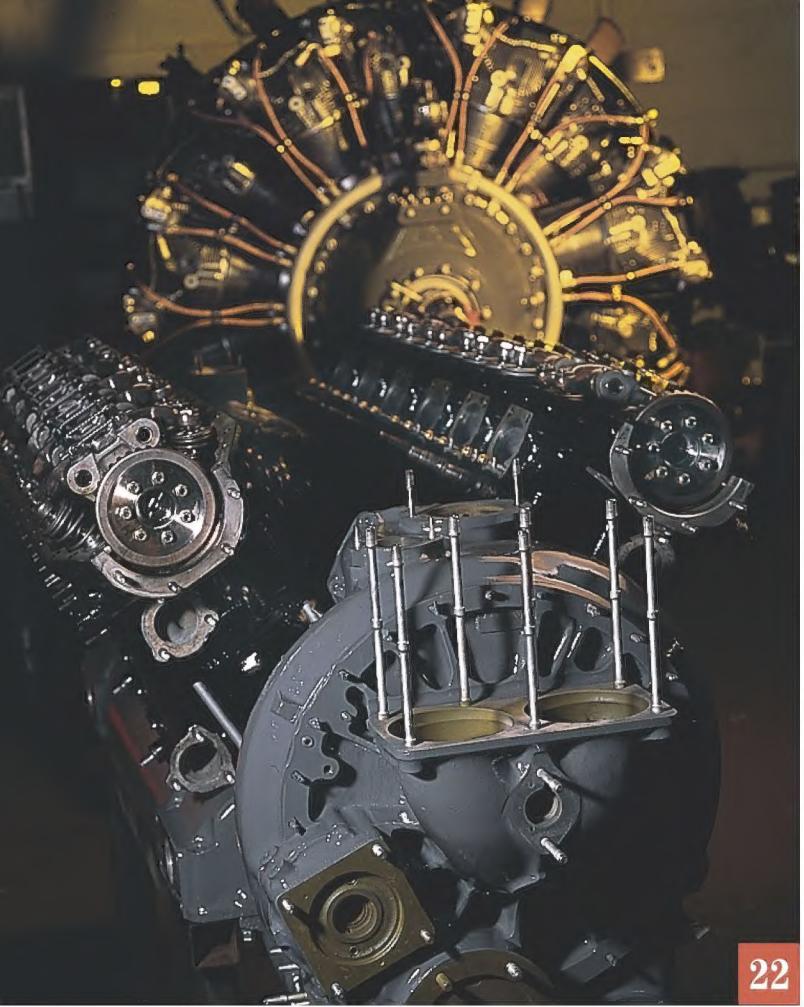
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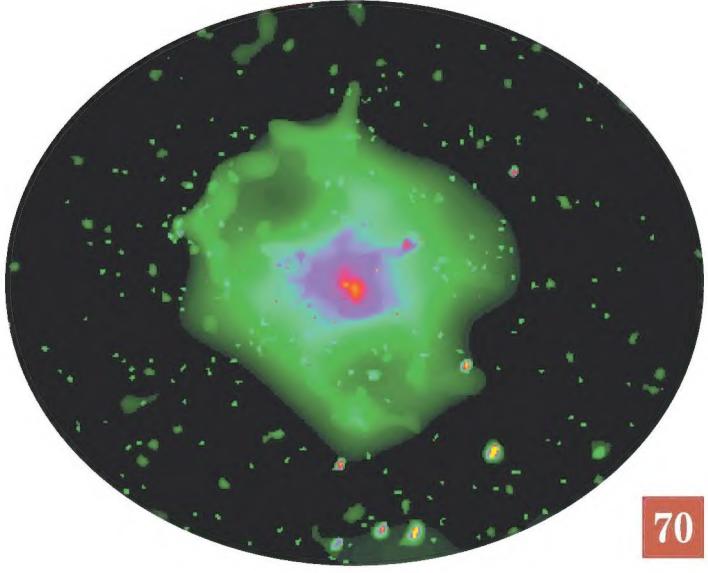
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22



44



70

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Smithsonian

February/March 2002
Volume 16 • Number 6

FEATURES

22 Masters of the V-12 by Stephan Wilkinson
Keep your mitts off those Merlins. You wouldn't tune your own piano, would you?

32 Building a Great Air and Space Library
Photographs by Eric Long
From Jane's All the World's Aircraft to Fate Is the Hunter, here are the classics of aerospace literature, plus a few new titles for your collection.

42 Restoration: Delightfully de Havilland by Diane Tedeschi
The prettiest little airliner we ever saw, and—bonus!—it's for sale.

44 I Survived the Rotary Rocket
by Marti Sarigul-Klijn
What's so difficult about flying a six-story-tall rotorcraft shaped like a traffic cone?

50 "This Is Only a Test" by Roger A. Mola
Photo illustrations by David Povilaitis
Long before the United States felt the threat of terrorism, the military grounded the airlines to prepare for World War III.

56 How Things Work: Shuttle Launch Windows
by Eric Adams *Illustrations by John MacNeill*
Space shuttle launches must run like clockwork. Here's how the clockwork works.

58 The Plane With No Name
by William Triplett
Photographs by Chad Slattery
What's in a name? A "Fighting Falcon" can't touch this.

68 Commentary: Block That Nuke
by Bruce Berkowitz
Focusing solely on terrorism, the author argues, could expose us to far worse havoc.

70 X-ray Eyes
by James S. Schultz
The Chandra X-ray Observatory is the ambulance chaser of high-energy astrophysics.



32



Cover: From a hilltop in Australia, Chad Slattery stalked and shot the swing-wing, Mach 2, terrain-following, ground-pounding F-111 during its afternoon training exercise.

DEPARTMENTS

4	Viewport	78	Sightings
6	Letters	80	Reviews & Previews
10	Soundings	82	Calendar, Credits
16	In the Museum	83	Forecast
18	Above & Beyond	83	On the Web Site
20	Oldies & Oddities	84	Moments & Milestones

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Engine Rooms

In 1889, Smithsonian Secretary Samuel P. Langley acquired for the National Collection a small one-horsepower steam engine built by aeronautical pioneer John Stringfellow. Langley was working on heavier-than-air powered flight, and he took great interest in the little engine, which became the first aeronautical artifact acquired by the Smithsonian and is now part of one of the world's premier aero propulsion collections. That collection includes 368 reciprocating piston engines, 432 propellers, 131 gas turbine engines, and 788 associated items. Some artifacts are the only surviving remnants of famous aircraft.

For their heavier-than-air vehicle, Wilbur and Orville Wright had to design a lightweight engine from scratch. The engine, which is still mounted in their 1903 *Flyer*, turned out to be the first of many. The Museum has two examples of the Vertical 4 engine, one of which powered a 1912 Wright B-1 hydroaeroplane and is the oldest surviving aircraft engine ever operated by the U.S. Navy.

To mobilize U.S. industry for World War I, automotive engineers Elbert J. Hall and Jesse G. Vincent designed the Liberty engine (it took them only six days). U.S. auto workers produced 20,000 before the war's end. The first Liberty engine is on display in the Museum's World War I gallery. The U.S. propeller and woodworking industries also answered the call, and examples of their work will be displayed at the Museum's Steven Udvar-Hazy Center in Virginia.

The Air Transportation gallery houses a Pratt & Whitney Wasp and a Wright Whirlwind, radial engines that fostered the growth of aviation—a Whirlwind

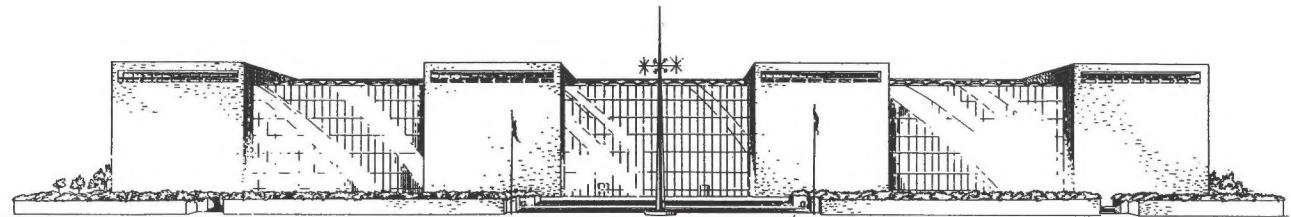
powered Charles Lindbergh's 1927 transatlantic flight. Sanford Moss of General Electric mounted a turbo-supercharger on a Liberty engine to recover power at high altitude. The pilot could adjust the blade angle of the Army-developed variable-pitch propeller so the airplane could operate more efficiently. Moss' engine and the variable-pitch propellers will be on display at the Udvar-Hazy center in 2003.

The Whittle W1.X turbojet, the first British jet engine to fly, can be seen in the museum's Jet Aviation gallery. Our restoration specialists have just finished preservation of the Ne-20 turbojet, which powered the Japanese Nakajima Kikka jet fighter—one example of Japanese and German engines in the collection.

During the early days of the cold war, we had to decide: propellers and pistons or the turbojet? The U.S. Air Force went in one direction with the world's largest aeronautical reciprocating engine, the 36-cylinder, 5,000-horsepower Lycoming XR-7755-3, but it never flew. In the collection are the prototypes of the J57 turbojet and the JT3D turbofan, which powered the first generation of military and commercial aircraft as Pratt & Whitney established its name in jets. All three of these engines are scheduled for display at Udvar-Hazy in 2003.

The Smithsonian has acquired many rare and unique aero propulsion artifacts, but there are still engines, propellers, and related components that the Museum does not have. The large exhibition and storage areas at the Udvar-Hazy Center ensure that this collection will continue to grow.

—J.R. Dailey is the director of the National Air and Space Museum.



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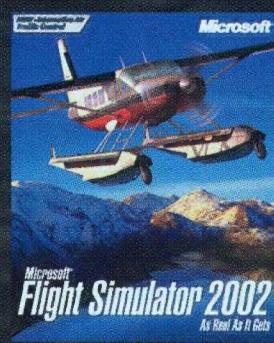
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LETTERS

Danger in the Desert

When I first checked in at Nellis Air Force Base in 1953, the group commander, Colonel Hinton, turned to his secretary and said, "Here's a man that has made a remarkable recovery from being a B-29 navigator to being a fighter pilot" ("Air Combat U," Dec. 2001/Jan. 2002). That was the beginning of my five and a half years at Nellis. A non-flying officer and I established the Special Weapons part of the Academic Section that all the students went through. Robert Hanson was no doubt in my classes. Later, I was an instructor in the Fighter Weapons School. Jack Bennett, whom Hanson writes about, George Rudder, and I were sent to Europe in the summer of 1957 to brief our F-86 pilots on the F-100, which would soon replace the F-86 there. Hanson's depiction was "right on"; the Hun (we called it the Lead Sled) had some fearful idiosyncrasies that tolerated no carelessness.

Those years at Nellis were tough on airplanes and pilots. During the first 32 months I was there, 18 instructor pilots bit the dust. At times we lost a student a week. Headquarters in San Antonio became desperate and announced that the next instructor who lost a student would be court-martialed. One instructor was actually tried. One of the questions put to him was "Did you brief your student not to fly into the ground?" (He was acquitted.)

In response to the reader who asked whether F-4 pilots from Nellis flew below sea level in the deserts of California (Letters, Dec. 2001/Jan. 2002): During my time there, it wasn't uncommon to take students in the formation phase of training to Death Valley so that they could fly below sea level. We would also take students down into the Grand Canyon, but stopped when the base got a notice that a cable was to be rigged across the canyon in order to mine bat guano from a cave on the opposite wall.

Another thing we used to do (since you cannot hear your own sonic boom in the cockpit) was climb to about 25,000 feet in an F-86, tune in a local AM radio station on the radio direction finder, split S, and, diving with the gunsight on the broadcast building, go through Mach 1 and then pull out. If a live broadcast was being made, you could hear your boom over the radio.

—Lee A. Brewer
 Friday Harbor, Washington

I have had lots of negative-altitude indications crossing the Salton Sea on training missions. Last month I drove around the sea, and after seeing the size of the birds there, I realized I'd been lucky to never have a strike.

—Charles Smith
 Wills Point, Texas

The Below Sea Level Club has at least four members who are Marines. On our way home from Cherry Point to El Toro, we lit the burners of our F-4s and went warp speed through the entire length of Death Valley, at way below sea level.

—Patrick Curtis
 Sherman Oaks, California

September 11

September 11 was about lives given and lives lost, not a "repudiation" or "desecration" of *things*, as you phrased it in your editorial (page 3, Dec. 2001/Jan. 2002). Airliners are the safest form of transportation because of the *people* who build, maintain, control, and fly them.

—Joe Medoro
 San Diego, California

In "Aftermath" (Dec. 2001/Jan. 2002) Lester Reingold reports that one idea for enhancing aviation security is an arrangement whereby, in the event of terrorists taking control of a cockpit, an air traffic controller could go over a captain's head and issue commands directly to the airliner's autopilot. That idea had occurred to me earlier, not because of terrorism but because of an aviation tragedy caused by loss of cabin pressure. A professional golfer and all other occupants of the business jet in which he was flying lost their lives in a bizarre tragedy in which the aircraft interior lost pressure and everyone aboard lost consciousness. The aircraft, which was on autopilot, continued to fly until it was out of fuel. It is fortunate that it didn't fly into a building. An air traffic controller who had control over the plane could have ensured that that wouldn't happen.

—Alexander R. Kovnat
 Bloomfield Township, Michigan

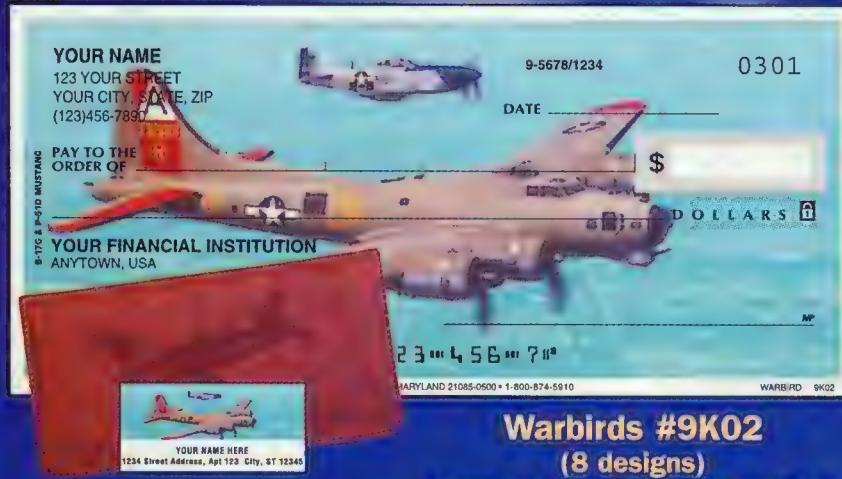
I want to point out that the photo of the F-16 in "A Mission Expanded" (Soundings, Dec. 2001/Jan. 2002) shows one of our Green Mountain Boys, who fly for the Air National Guard Unit based in Burlington, Vermont. I believe the photograph was shot on September 12.

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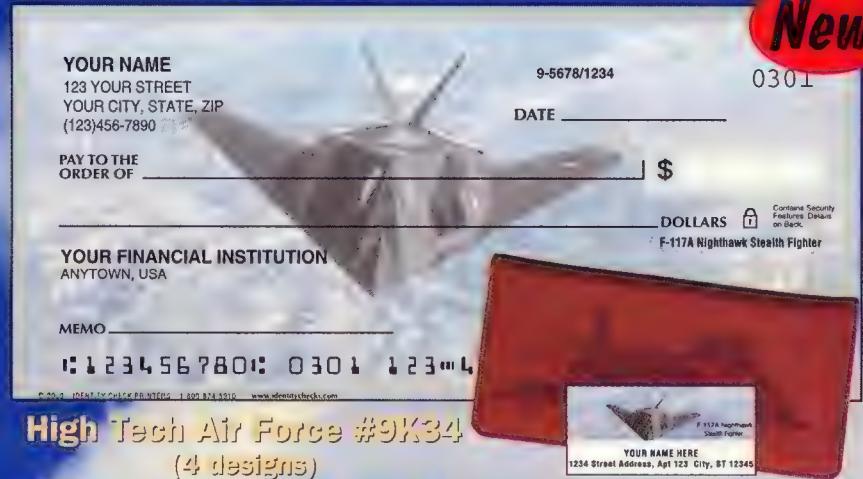
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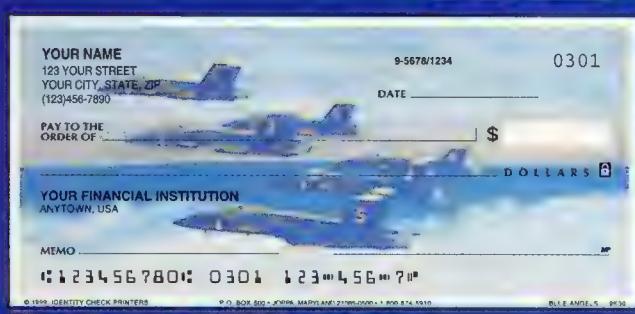
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Note the smoke rising where the World Trade Center towers were.

—Arthur A. Dionisio
Wheeklock, Vermont

In "A Mission Expanded," Tim Wright writes that Air Force jets were on alert before the September 11 attacks. Was it normal to have jets in Massachusetts on alert? I can understand jets on constant alert in Washington, D.C., but not in Massachusetts.

—Ray Karlin
Tucson, Arizona

Editors' reply: The Air National Guard fighters in Massachusetts, Virginia, and North Dakota were indeed on alert before September 11. Any number of units are on alert at all times around the country for national defense.

Front Row at Heathrow

Yet another excellent place to watch, smell, and almost touch aircraft from all around the world ("Airports of Call," Aug./Sept. 2001) is the observation platform on the roof of Terminal 2 at London's Heathrow Airport. You are situated right in the middle of the two active runways. Recently, I was able to watch aircraft from all parts of the world arrive and depart at very close intervals. Truly a planespotter's paradise.

—Peter Butchart
Nelson, New Zealand

A French Seiran

Although the Seiran was the first submarine-launched attack aircraft ("All and Nothing," Oct./Nov. 2001), another aircraft was the first to be part of the regular equipment of an operational

submarine. The French Surcouf, which at the outbreak of World War II was the world's largest submarine, was designed, like the Seiran, to carry an airplane. French naval authorities have kindly supplied me with a detailed account of Surcouf. It had a conning tower extending aft to form a hangar, which enclosed a Besson spotter floatplane (wings detached). When the crew members were ready to launch the plane, the plan was that they would reattach the wings, and then a hull-mounted crane would lower the craft onto the sea surface (and subsequently retrieve it).

In June 1940, Surcouf left Brest to join the Free French naval forces and operate in the Atlantic on convoy and other duties. A decision was made to send her to the Pacific to strengthen the French presence there, coincidentally via the Panama Canal, which the Seiran had been designed to attack. In February 1942, the sub was proceeding through the Caribbean at night with all lights extinguished, still 75 miles from the canal, when she collided with a cargo vessel and sank with all her crew and equipment, including the Besson aircraft.

—Derek W. Newson
Somerset, England

Flutter: It's Not Just for Airplanes

Although I am an aerodynamic structures type, several years ago I worked on an unusual ground-based application involving the flutter phenomenon ("The Hammer," Feb./Mar. 2001). It involved the nuclear certification of a nuclear weapons carrier, a process that included guaranteeing that the vehicle could not break up and cause an accident.

Prior to my interest in the project, the assigned personnel would do this empirically, loading the vehicle with dummies and driving it over a "Belgian Block" track to try to make it fail. It never failed because it was huge, heavy, and stiff, but that did not prevent some time-consuming and very expensive "testing." And when it came time to design a new carrier for the Minuteman reentry vehicles, the requirement to build it heavy and stiff made it impossible to meet road and transport criteria—a Catch-22 if there ever was one.

What we did was measure the road surface to be traveled and apply that input vibration load to the chassis design, making sure we stayed away from resonant points. The result was a complete success: The vehicle was lighter and stronger and had no tendency

to fatigue or to fail from sympathetic vibration. We could now determine all the relevant factors with a few simple measurements and adequately certify the vehicle as safe to carry nuclear weapons. The key, of course, was understanding the natural frequencies and the induced vibrations during normal operations.

—William D. Montjoye
(U.S. Air Force, ret.)
President/CEO, ADM Technology, Inc.
San Antonio, Texas

You Can't Keep a Good Avenger Down

A couple of us old guys in Nova Scotia enjoyed "The Avengers" (Oct./Nov. 2001), but you did not highlight a bright spot in the aircraft's history. In April 1950, the Royal Canadian Navy Fleet's Air Arm acquired 75 Avengers from the United States to fly from Canada's only aircraft carrier as anti-submarine aircraft.

These Avengers were processed through the Fairey Aviation Company of Canada in Nova Scotia, where they were extensively modified for anti-submarine warfare. (We are former Fairey Aviation employees.)

These "turkeys," as they were affectionately called, did yeoman service for the RCN and won their share of awards in NATO exercises. They were replaced in the late 1950s by the Grumman Tracker, built under license by de Havilland in Canada.

We think the Avenger on the cover of your November 2001 issue was one of ours, obviously modified again!

—Brian Ridgeway and Loring Gates
Dartmouth, Nova Scotia, Canada

Correction

Dec. 2001/Jan. 2002 "Rocket Ships": The Bumper's second stage was a liquid-fuel Wac Corporal, not a solid-fuel rocket.

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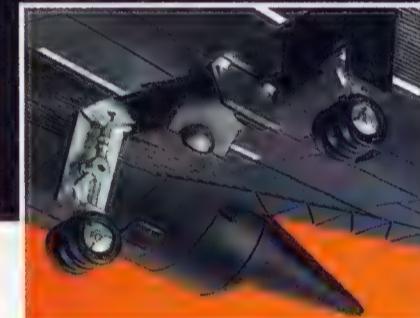
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Tastes Just Like NASA Used to Make

Back in the heady days of 1997, when the Internet bubble was rising like a warm soufflé, Houston's rock 'n' roll DJ Dayna Steele Justiz decided to cook up a recipe of her own: To overcome her fear of computers, she'd whip up a Web site to sell a few NASA goodies and trinkets (which are produced and sold by non-NASA companies). After drawing pictures of what she wanted her site to look like, husband Charlie Justiz—a NASA research pilot who flies the KC-135 zero-G Vomit Comet—wrote the code. "You can get a lot done on your Web site when you sleep with your web master," Dayna jokes.

But what really got her site, thespacestore.com, cooking was Justiz's decision last June to sell real-life astronaut food over the Web. She approached NASA's chef, Johnson Engineering of Houston, and discovered she could order the same food the space agency serves as long as she placed the order at the same time. "I put the food on the Web site and put out a press release," she says. In no time she sold out of just about everything. "I started with beef

fare that was freeze-dried and that astronauts rehydrated in space. Food planners then experimented with off-the-shelf MREs—Meals Ready to Eat—which they found contained more sodium and fat than the relatively languid space travelers needed.

Two years ago NASA started cooking

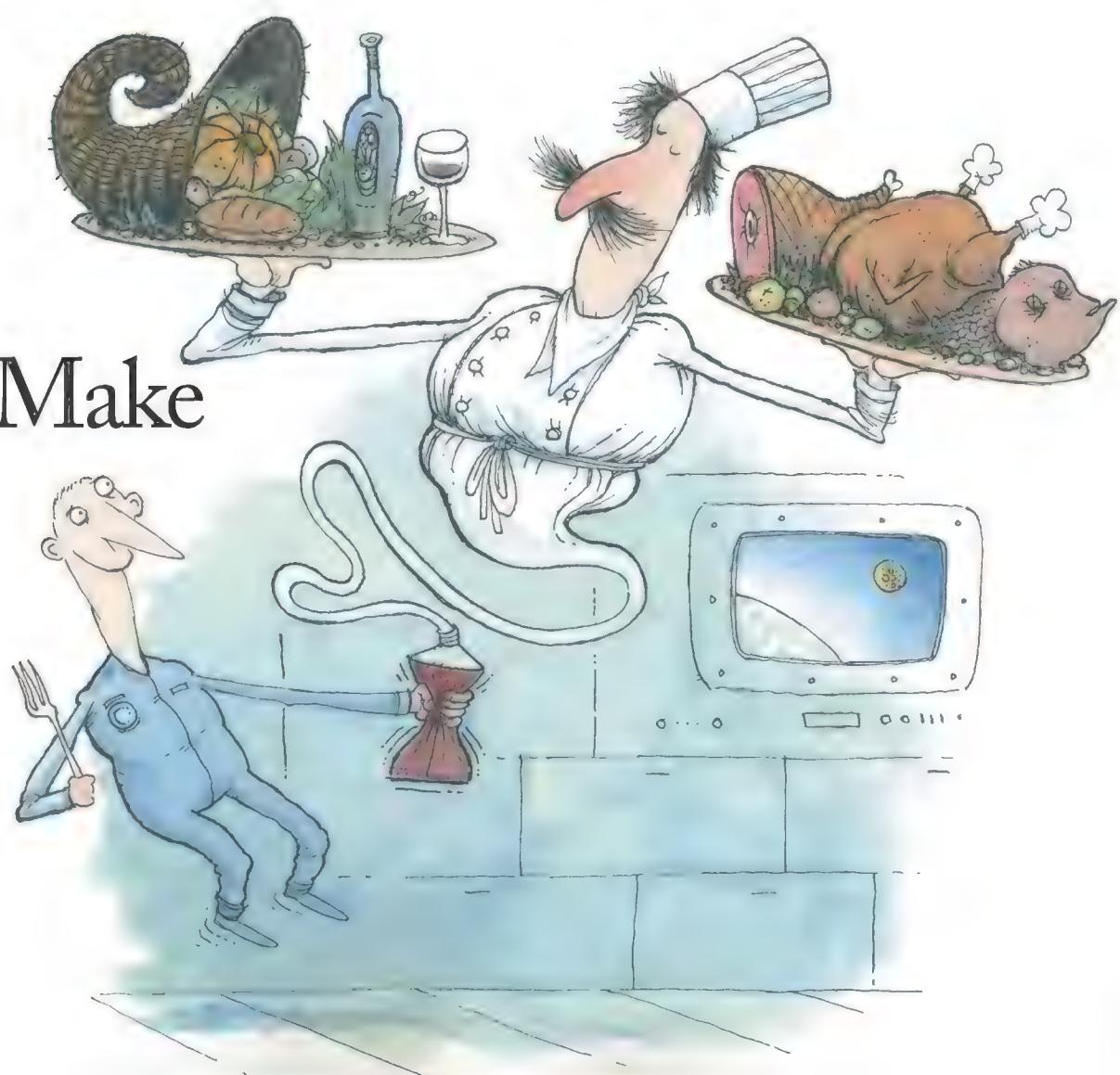
Floridians buy it for hurricane kits, Californians get it for earthquake kits, and Houston's Associated Press chose it for reporters to take along in their cars. Even a few survivalists have had the pouches shipped to their enclaves.

stew, minestrone, chicken and potato soup, peach yogurt, cherry cobbler, chicken fajitas, and meatloaf. We sold out of everything but meatloaf, fajitas, and minestrone," Justiz says, but to be fair the site actually had more minestrone than anything else. "My personal opinion—I don't like minestrone here on Earth," she adds. "Meatloaf is my favorite. And the bread pudding is a huge hit."

The food, which tastes like something between cafeteria food and Lean Cuisine, is relatively new to NASA. Realizing that astronauts cannot live by tubed goo alone, the agency had previously offered

up the new meals. The thermostabilized food is hermetically sealed in a silver laminate pouch and sterilized at 250 degrees for 30 to 40 minutes. "As long as the packaging is unopened or unpunctured, the food will remain shelf-stable," explains Beverly Swango, Johnson Engineering Space Food Systems Laboratory Manager.

So who's buying space victuals? For a start, health food folks are interested because it's low in sodium and fat. Floridians buy it for hurricane kits, Californians get it for earthquake kits, and Houston's Associated Press chose it for



DAVID CLARK

reporters to take along in their cars. Even a few survivalists have had the pouches shipped to their enclaves. Campers find it easy to cook—just drop the pouch in water. But perhaps the happiest camper is Dayna Steele Justiz herself: She sold her company to Space Media Inc. For how much, she's not telling. "Suffice it to say I was pleased," she says.

—Phil Scott

Space: The Routine Experience

In a ceremony befitting the routine nature of space shuttle flights, the U.S. Astronaut Hall of Fame inducted its first four space shuttle fliers last November. The Titusville, Florida temple to America's highest-flying heroes abandoned its usual black-tie fanfare and invited anyone who could afford an \$85 ticket to watch as Robert Crippen, Joe Engle, Frederick Hauck, and Richard Truly were enshrined.

Crippen piloted the shuttle's maiden voyage, STS-1, in 1981, commanded three other missions, and went on to become the director of NASA's shuttle program. Engle, a former Air Force X-15 pilot, commanded three shuttle flights—an unpowered

UPDATE

Micco: On Hold

Micco Aircraft Company has all but closed its south Florida factory, apparently due to the ousting of Chief James Billie ("The Seminoles' Corvette with Wings," *Soundings*, Apr./May 2000). Last May, Billie was removed as tribal chairman while he awaited the outcome of a sexual harassment suit and a financial audit. Additionally, a federal grand jury is investigating embezzlement charges. The aircraft company is for sale, and no more Micco SP20s and SP26s will be built until a buyer is found. Last year the company sold 12 aircraft.

approach-and-landing test by the *Enterprise* in 1977, as well as orbital missions STS-2 and STS-51I. Truly, Engle's right-seater for the landing test and STS-2, commanded STS-8 and served as NASA administrator during the agency's recovery from the *Challenger* disaster. Hauck, a veteran of STS-7 and STS-51A, commanded the first post-*Challenger* mission, STS-26, in September 1988.

"Space shuttle astronauts are truly unsung heroes of the space program," says Apollo 13's James Lovell, chairman of the Astronaut Scholarship Foundation, which hosted the event at the Visitor Center at Kennedy Space Center in Florida and oversees operation of the nearby Hall of Fame. "Many people don't realize that the shuttle was the first vehicle to launch men into space without being previously flight-tested unmanned. It's radically different from the spacecraft used in the Mercury, Gemini, and Apollo missions."

Trailblazers all, but—unlike many of the 44 daredevils installed before them—Crippen, Engle, Hauck, and Truly are not exactly household names. Except to the United Airlines pilot who flew from Maryland with his less interested wife and son in tow. Or to Eamonn Cregan, a cattle farmer from Ireland who was also among the few thousand people who attended the two-day celebration. "Every time [a shuttle] goes up, they fail to communicate what a modern-day miracle it is to launch human beings in space," says the 32-year-old. "It is NASA's greatest failing."

The event was advertised to space buffs and autograph hounds worldwide as the largest gathering of astronauts ever on Florida's Space Coast. Twenty-two were introduced to the crowds; at least 10 no-shows left the conclave smaller than the 27 who had appeared for the glitzy induction of Apollo hall-of-famers in 1997.

What luck for Cregan that most of the crowd wanted to press the flesh with heroes of the bygone eras. They so preoccupied Kennedy Space Center's

security detail that Cregan managed to steal considerable face time with several of his shuttle favorites, who were largely being ignored.

Anonymity, Crippen allowed, is the reward for being a shuttle astronaut. "Our intent with the space shuttle was to try to come up with a vehicle that was going to make it fairly common going into space," he says. "Our objective was to make it a more routine experience."

—Beth Dickey

Cheapsat

In late September, an Athena-1 rocket at Alaska's Kodiak Launch Complex carried into space a Prototype Communications Satellite (PCsat) designed and built inexpensively over three years by 16 midshipmen majoring in aerospace engineering at the U.S. Naval Academy in Annapolis, Maryland. When administrators had hesitated to provide the \$500,000 thought necessary to construct the satellite, the academy's Small Satellite Program director, Air Force Lieutenant Colonel Billy Smith, and director of aeronautics Daryl Boden figured out how to do the job for about 90 percent less.

"The primary project was to get the

students involved in actually building something," says Bob Bruninga, who operates the USNA Ground Satellite Station. Initial news reports made it sound like the middies built their satellite by running to Radio Shack, but Bruninga says, "Actually, I don't think there are any parts in there from Radio Shack."

"It costs a lot of money to space-qualify electronic hardware, so we just went down to any supplier who had what we wanted and ordered through the catalogue," says Boden. And instead of buying a flight-ready \$50,000 antenna, the group cut eight strips from a \$15 stainless steel Stanley tape measure. "Four of those antennas are six inches long and support the UHF transmitters and receivers," Smith says. "The other four are 19 inches long and support the VHF transmitters and receivers. The body of the satellite is a cube, 10 inches on a side, with a fly-away mass of about 25 pounds."

Boden adds, "After we obtained the parts, we did some thermal vacuum and vibration tests, here and at the Naval Research Lab, to convince ourselves that they would work in space."

PCsat, now North American Aerospace Defense Command object #26931, "is used to relay communications between amateur radio operators on the ground,"

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As part of a \$1.5 billion expansion of the house the mouse built, Disney's California Adventure captures the heart of the Golden State, from Napa Valley to Yosemite, in 55 asphalt- and fiberglass-covered acres. While Paradise Pier and Hollywood Back Lot provide more than enough theme rides and shows for the average family, it is Condor Flats, fashioned after a high desert landing field, that will make prop-head imaginations soar.

Condor Flats attempts to re-create the Air Force testing grounds of the 1940s, with buildings that resemble old hangars and streets transformed into runways. While the Taste Pilots' Grill and Fly 'n' Buy are hardly worth the time, Condor Flats makes it up to visitors with Soarin' Over California, which uses three rows of "hang glider" seats to lift the audience 40 feet over a giant curved IMAX screen. For five minutes viewers soar and bank over farms, rivers, skiers, hot-air balloons, the coast, the desert, San Francisco Bay, and, of course, Disneyland, buffeted by occasional minor turbulence and treated to the scent of orange groves, pine forests, and beaches. Watch out for the duffer on the back nine at Pebble Beach with the wicked slice.

—D.C. Agle

says Bruninga. "Its specific mission, unique to this satellite, is that users relay their GPS coordinates between each other."

The USNA Small Satellite Program has been funded largely by Boeing, which is giving the group \$50,000 a year for five years. "They thought if we could do one satellite in five years, for what they gave us, they would be impressed," Boden says. "We told them up front that we planned to do a satellite every other year."

Future USNA satellites will not replicate #26931, says Smith. "Our goal is to have the project evolve so that each satellite is more challenging, more complicated than the one that came before it."

—Richard Sassaman

Fly Green

We're all familiar with electric cars, those well-meaning vehicles driven by the granola set that burn no fossil fuels and travel up to 50 miles without a recharge—and do so quietly in the bargain. Now a Massachusetts man is developing what he says will be the world's first electric-powered piloted airplane. "We do a lot of off-the-wall visionary things," says Jim Dunn, president of Advanced Technology Products, "but of anything I've ever done, this has garnered the most amazing reaction."

Dubbed the E-Plane, or Electric Plane, the composite two-place aircraft will be equipped with an electric motor driven at first by lithium batteries that will give the E-Plane an optimum speed of 83 mph and a range of 100 miles. Unveiled last July at the Experimental Aircraft Association's Oshkosh, Wisconsin fly-in, the E-Plane will make its first flights sometime this year. Eventually the aircraft will be outfitted with a combination of batteries and a fuel cell for a 250-mile range; ultimately it will fly solely on a fuel cell and have a 500-mile range. Unlike batteries, which store electricity, fuel cells generate the stuff—so long as they're fed hydrogen and oxygen. Their sole byproduct is water.

"We don't have any engine noise—it makes a whir but you don't hear that," says Dunn. "We still have propeller noise, but there's no emission of any kind." And there's one other selling point. "It does have a low thermal signature," he adds, "so for military purposes it's very stealthy."

Dunn is no novice to new technology:

Thanksgiving at Sea

An e-mail to a friend from a pilot (who requested anonymity) aboard the U.S. Navy aircraft carrier Theodore Roosevelt, North Arabian Sea, late November 2001

For Thanksgiving, the ship dressed up the wardroom, dimmed the lights, and put out a nice T-day spread and, for a brief moment, it was almost like being home. Sure it was. I don't know too many folks who live in a gray tin can with 5,500 other roommates, but what can you do? We had flights later in the day scheduled, so scores of aircrew had to fight off the tryptophan nods during their six-hour flights over Afghanistan. I was able to call home and chat briefly with the kids, who filled me in on the untimely passing of their second fish. "It's okay, Daddy. We'll get another one." It was a great day.

The bombs keep falling on the Taliban. Sometimes you get in-country and drop, sometimes you can't. As you can gather from the news coverage, the ground picture is changing radically and as a result, the air strike players are a bit more restrained.

Talked previously about air-to-air refueling. Cool tanker guys? The Royal Air Force! They always go the extra mile (literally) to make sure you get your gas when and where you need it. The RAF tankers are always on station and on time. Apparently, the F-14 is their favorite platform so as an added benefit post-tanking, you can pull up along side the pilot's window and he'll shove some literature up against the window for your perusal (you guess the type of literature displayed).

To get gas airborne we have to deploy a refueling probe, which extends out from the right side of the jet about two feet outboard and forward of the pilot's head. The tanker is dragging a 20-foot hose that ends in a basket similar to a badminton birdie, but about two feet in diameter. Now, the hardest part of tanking at 300 mph is getting in the basket, because as you near it, the air disturbance created by the nose of your jet

ERIK HILDEBRANDT



causes the basket to move up and away from you. Also thrown into the equation is general air turbulence, as well as the "ham fist" of the pilot flying the tanker. Sometimes you get in the first time, sometimes it takes a couple of stabs.

A few days ago, we were directed to hang on this RAF tanker's wing until we received mission tasking. The RAF guy says, "If you F-14 chaps are truly America's Finest Fighter Aircraft, then you should have no problem getting into the basket first time, right?" I respond with, "Yeah, I usually bat about .900 with these poorly designed Brit baskets. The problem is that when I get in close, I find myself thinking about Margaret Thatcher naked, get sick to my stomach, and miss the basket. Tell you what, we'll put a case of beer on both Tomcats getting in the first time."

Bet's on. The call finally comes for us to go hit some targets and it's time to get topped off. I head over to the tanker's left wing, my wingman over to his right, and as we are closing in I tell him, "Now, as you get in close, try not to think about all of the great English warriors of the past: the Spice Girls, Boy George, Wham UK, and Dame Edna. Just free your mind and be the basket."

A couple of corrections later and just as I plug (on the first attempt), I shout over the radio, "Revolutionary War, baby!" My wingman was good on his first attempt, so the final score was U.S. 2, England 0. I doubt we'll see the beer but who would want a case of warm Brit beer anyway?

Speaking of beer, somewhere in the Navy regulations it says that for every 45 consecutive days that you spend at sea without a port call, you rate two beers. Two weeks ago, they broke out 10,000 beers for the crew to tear into for this deployment's first of many "beer days."

Hope this e-mail finds you all safe and having a great holiday season. Don't worry about us, we are doing great out here. I can honestly say that there is no other place in the world I'd rather be than right here, right now, sticking it to the Taliban.

"I can't wait to get to the next building and see what's there!"

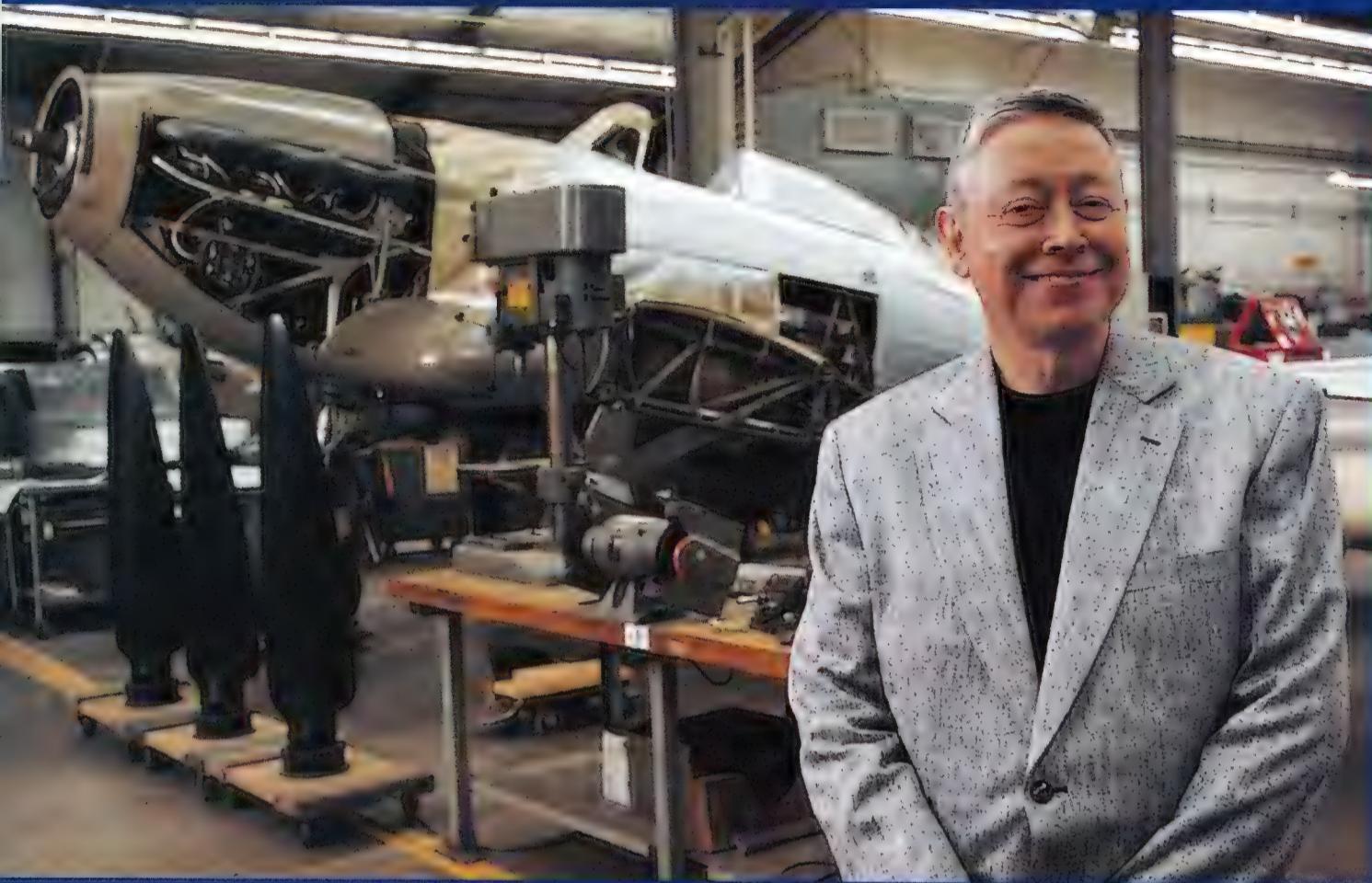


PHOTO: ERIC LONG

When Earl Clayton tells co-workers he's going on vacation, they ask, "To see airplanes again?" You see, Earl is a genuine, lifelong aviation buff. He's happiest prowling the buildings of the Smithsonian's Paul E. Garber Preservation, Restoration and Storage Facility, which houses the majority of the National Air and Space Museum's collection.

Preserving the history of flight is why he's

"Being part of the Smithsonian Legacy Society is one of the most rewarding things I've ever done."

—EARL CLAYTON and the legendary Hawker Hurricane at the Smithsonian's Paul E. Garber Facility, one of Earl's favorite places in the world.

also a member of the Legacy Society — one of many generous individuals who has included the Museum in their will.

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One of the inventors of the laptop computer ("I still hold two patents," he says), he built electric-powered bicycles in the early 1990s before turning to an electric fuel-cell automobile. It competed in the 1996 American Tour de Sol, a race for alternative fuel vehicles, and it took the trophy for most innovative. As a pilot, Dunn had no doubt as to his next step. "In the 100 years since the Wright brothers, we've had progress in aerodynamics and in navigation, but we haven't done anything in propulsion other than the turbine," he says. "Now we're beginning a whole new paradigm—of electricity."

Last December, NASA awarded Dunn a grant from its Revolutionary Aeropropulsion Program to assist in development of the E-Plane. Once he has a certificate for a propeller-driven aircraft—after 2004—Dunn says he'll be working on a high-speed ducted-fan aircraft. It's already on the drawing board.

—Phil Scott

Caller ID

A clever rogue state gets hold of a low-speed, low-altitude unmanned aerial vehicle and modifies it to carry an explosive. The military flies it up the coastline at 50 mph and 100 feet, then follows a road toward a heavily defended nuclear power plant. The UAV is under active surveillance by ground-based radars and Airborne Warning and Control Systems, yet still manages to blast the station to smithereens. Why? Conventional radar interpreted its blips as echoes from road traffic.

Roke Manor Research in Great Britain has developed a setup that could have detected the UAV with a network already in use: cell phones. CELDAR is a passive system that uses reflections from cell phone towers' electromagnetic signals.

The system is in its early stages, but Peter Lloyd, Roke's chief designer, says it can already detect targets "up to tens of kilometers away." At a small airfield near Salisbury, England, last November, some potential military customers watched as CELDAR detected signals in real time from

HEADS UP



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Iance to the Big Band music of the 1940s aboard the USS *Hornet*, which garnered an unmatched combat record in World War II and served as the recovery ship for the Apollo 11 and 12 missions. The carrier, also known as CVS-12, was designated a National Historic Landmark in 1991 and in 1998 opened to the public as a museum. Aircraft on board include a Grumman TBM Avenger and F9F-5P Panther, a Vought F7U Cutlass and F8U-1 Crusader, a McDonnell Douglas A-4A Skyhawk, and a North American FJ-2 Fury.

Tickets for the event start at \$35. Proceeds benefit the *Hornet* museum's restoration and preservation projects. The museum runs a series of onboard educational and entertainment programs, as well as Protestant services every Sunday in the Wardroom Lounge, followed by refreshments.

the local cell base station bouncing off a slow-flying Scottish Aviation Bulldog monoplane. Roke won't divulge precisely how CELDAR works.

Lloyd says the system is not just for spying aircraft. "Our other work has enabled us to detect vehicles moving around on the ground, even behind foliage and at hundreds-of-meters-range," he says. He

expects that eventually CELDAR will also be able to detect larger aircraft at long range.

Roke says CELDAR would have a very low unit cost. Every cell would have a receiver and send its signals via the phone network to a command-and-control station small enough to fit inside the roof space of a government building, invisible to spy satellites. "The receivers would actually be composed of cell phone circuits just like the ones in the handsets we carry around with us," says Lloyd.

What to do when low-and-slow UAVs are detected? "It would be necessary to bring a weapon system to bear on the target," says Lloyd. "In the case of low-speed targets, we might even envisage a helicopter scooping them up in a net so as not to spill their potentially nasty cargo." Such techniques are nothing new. "During World War II," Lloyd says, "the RAF would often fly alongside the V-1 flying bombs and tip them over with the wingtips of their fighter planes."

—Graham Chandler

UPDATE

"Life Was a Whirlwind"

Moya Lear, wife of prolific inventor and Lear Jet line creator Bill Lear ("That 70s Airshow," Aug./Sept. 2001), died last December 5 at her home in Verdi, Nevada. She was 86 and had recently suffered a concussion, congestive heart failure, and a recurrence of lung cancer.

After her husband died in 1978, Moya tried to prop up his last project, the Learfan business jet, which was powered by two rear-mounted turbine engines turning a single rear-mounted propeller. But the Learfan project declared bankruptcy in 1985. When her autobiography, *Bill and Moya Lear: An Unforgettable Flight*, was published in 1996, she said, "The book should be called 'How to stay married to a rascal.' Our life was a whirlwind. [Bill] was full of hell." Moya then turned her attention to supporting development of the theater and arts in Reno.



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"People from all over the world come to see it," says one Museum security officer. "I've seen people kneel down and pray at it." On a busy day last summer, one teenager said: "It didn't feel like cheese." Others held back tears or even blessed themselves after seeing it.

The Rock

Within NASA it is known as sample 70215, 84. A geologist would classify it as a dense, aphanitic basalt. To visitors, however, it is one of the most popular objects in the National Air and Space Museum. "It" is the lunar Touch Rock, one of only three samples returned by the Apollo astronauts that the public is allowed to feel with their bare hands. On any given day, thousands of people wait patiently in line for a chance to examine this piece of the moon. Yet despite its popularity and prominent location in the Milestones of Flight gallery, near such artifacts as the *Spirit of St. Louis* and the *Wright Flyer*, few people know its history.

"So that's a moonrock, huh?" said a recent visitor. "I have a couple of those in my back yard." Depending on where he lives, he may—or at least he may have something like it. Basalts make up entire islands on Earth, such as Hawaii, and cover vast areas, including parts of the northwestern United States. On the moon, basalts are so prevalent that they can be seen as the dark patches, or maria, that

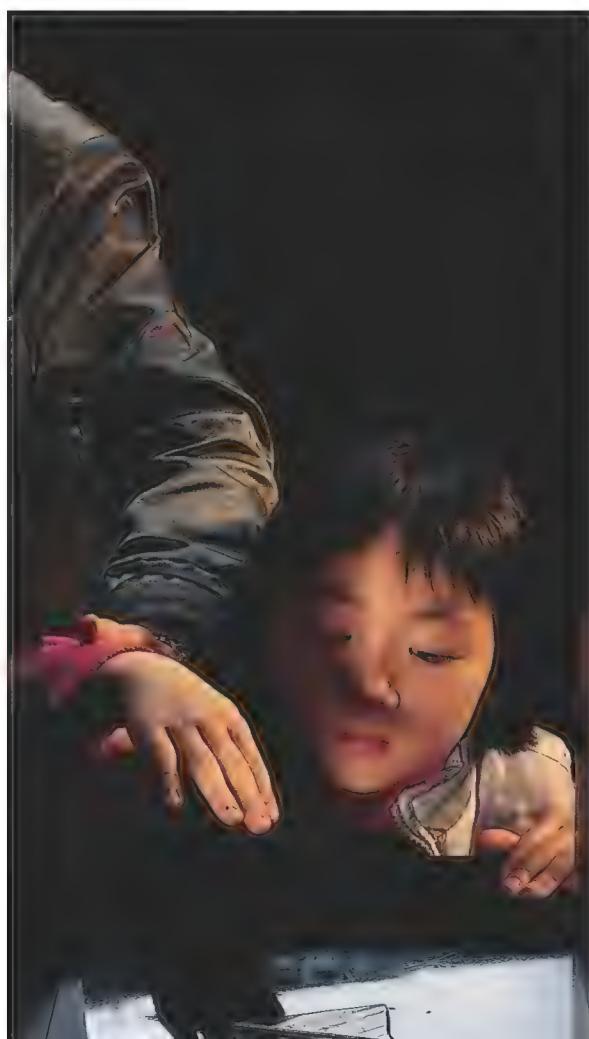
make up what appears to be "the man in the moon."

Between December 11 and 14, 1972, Apollo 17 astronauts Eugene Cernan and Harrison Schmitt explored the edges of

one of these patches, Mare Serenitatis, in a valley known as Taurus-Littrow. It was during their extra-vehicular activity—in this case a moonwalk—that Schmitt, a geologist by training, saw a rock that stood out from the others. All rocks cool from some original melt. If they cool slowly, they can develop large interlocking grains, or crystals. Such rocks were common in

Taurus-Littrow. This rock, however, looked out of place because it had no obvious grains. And it was very large. Instead of collecting it right away, Schmitt stood it on its side so he could come back to it later in case he and Cernan were not able to find something smaller. As their final EVA was winding down and they were returning to the lunar module for the last time, they came back and collected the rock that Schmitt had set on its side, sample 70215. The number identifies the mission, the rock's location, and the bag the rock was placed in for return to Earth. At 17.7 pounds, sample 70215 was the largest rock that the Apollo 17 crew brought back.

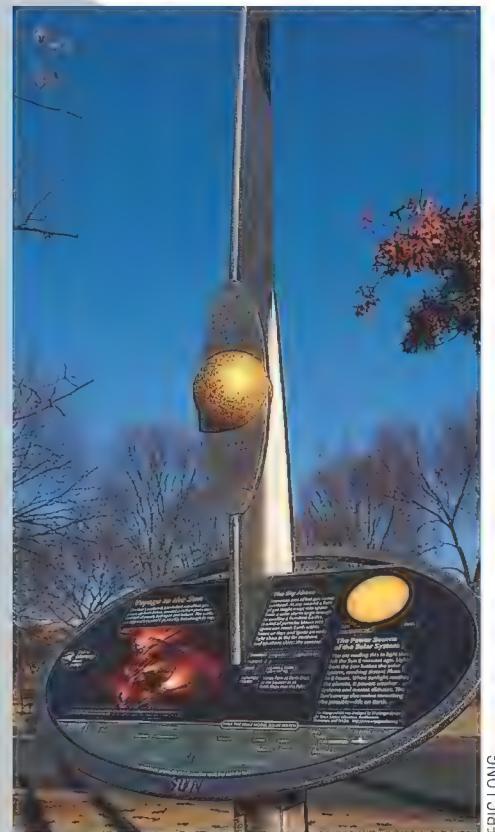
The Apollo lunar samples have been studied more than any other rocks. Sample 70215 was found to belong to a



CAROLYN RUSSO (3)

On the Mall

"Voyage: A Journey Through Our Solar System" opened on the National Mall on October 17. The permanent exhibit features a one-ten-billionth scale model of the solar system, which consists of 13 stainless steel stations set up along a 650-yard stretch of sidewalk that runs between the National Air and Space Museum and the Smithsonian Castle on Jefferson Drive. The stations are mounted with sculptures of the sun (right), planets, and asteroids.



ERIC LONG

group of moonrocks that contain large amounts of titanium and other elements so uncommon that they are considered rare Earth elements. Like all of the other lunar samples, 70215 does not contain water or volatile elements. Its chemistry can be explained by a widely accepted hypothesis that the moon formed when a Mars-sized object collided with the early Earth. Part of the object was instantly vaporized (along with parts of Earth) and thrown into orbit. The extreme heat from the collision drove away any water. Eventually the vaporized material coalesced into the moon, but it remained hot long enough for minerals to collect in a variety of ways. Basaltic materials sank into the interior to form the moon's mantle. Subsequent impacts carved away portions of the moon's crust, providing a pathway for basalts to erupt onto the surface. The impact that formed the Serenitatis Basin provided one such pathway, allowing basalts to flow into the neighboring Taurus-Littrow Valley. The dense, fine-grained nature of 70215 suggests that it cooled quickly, probably near the surface of one of these basalt flows about 3.7 billion years ago. Although fairly young by lunar standards, 70215 is the oldest thing many people will ever touch.

NASA, which carefully manages all 841.5 pounds of rock and soil the Apollo astronauts returned with, decided to donate three pieces of 70215 for public

display. Daughter sample 84 was loaned to the National Air and Space Museum in 1976, and the other two pieces are on display in Mexico City and at NASA's Johnson Space Center in Houston, Texas. Since 70215 is so large, there is still plenty left over for scientists to study. And its dense nature has allowed it to stand up to almost continuous handling; no pieces have ever come loose or broken off. Even so, it is under constant surveillance during the hours that the Museum is open to the public.

The security officers responsible for guarding it probably know better than anyone what a piece of the moon actually means to some visitors. "People from all over the world come to see it," says one Museum security officer. "I've seen people kneel down and pray at it." On a busy day last summer, one teenager said: "It didn't feel like cheese." Others held back tears or even blessed themselves after seeing it. The rock's popularity may best be explained by the reaction of an older couple, who walked away from it shaking their heads in disbelief. Didn't they think it was real? "I cannot believe that we did something that incredible, that fantastic," said the man. "It almost seems like a dream now, but here's proof. My God, what we can do when we put our minds to it."

—Bob Craddock is a planetary geologist at the National Air and Space Museum's Center for Earth and Planetary Studies.

February 20 Wernher von Braun Memorial Lecture: "An Evening With John Glenn." On February 20, 1962, John Glenn became the first American to orbit the Earth. On the 40th anniversary of this achievement, Glenn will reflect on his life as an astronaut and U.S. Senator. Tickets can be obtained at the Langley IMAX Theater box office or through Tickets.com by calling (800) 529-2440 or visiting www.tickets.com. Admission is free but Tickets.com charges a processing fee. Langley IMAX Theater, 8 p.m.

February 23 Family Day: African American Pioneers in Aviation. Listen to stories about the challenges African American aviators faced from 1920 to 1950, talk with Tuskegee airmen, and discover today's aviation career opportunities. 10 a.m. to 3 p.m.

March 9 Kite Day. Build and decorate a sled kite, explore the science of how kites fly, and watch a kite-flying demonstration. Free timed tickets for the event are available at the Special Exhibitions Booth in the south lobby. 10 a.m. to 3 p.m.

March 21 G.E. Lecture: "An Evening With Gary E. Krier." Test pilot Krier will talk about his experience with the F-8 Digital Fly-By-Wire flight research project. Langley IMAX Theater, 7:30 p.m.

Family Activity

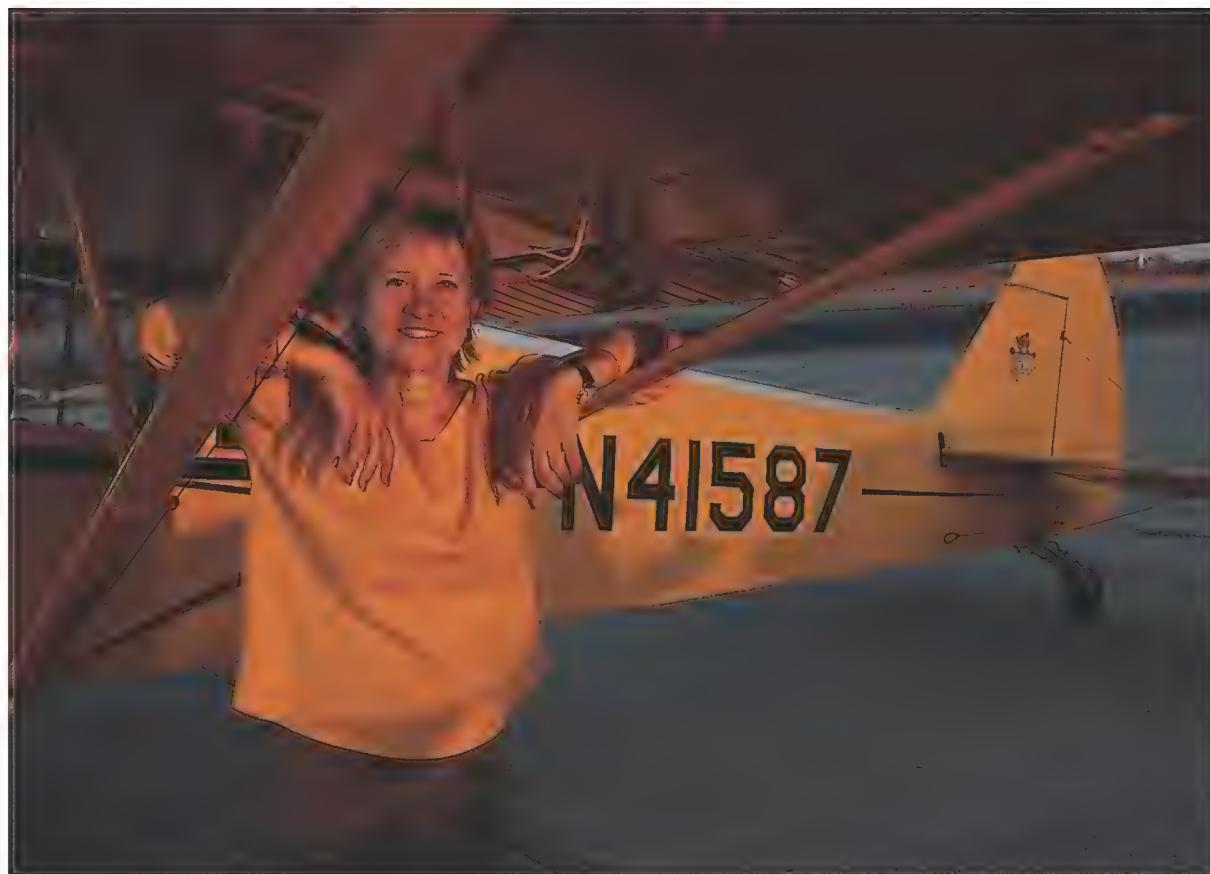
"Women in Flight: A Museum Treasure Hunt." Celebrate Women's History Month by picking up a treasure hunt guide at the Information Desk in the south lobby and following the clues to learn more about women aviation pioneers. Daily in March, 10 a.m. to 5:30 p.m.

Planetarium Renovation

The Einstein Planetarium will be closed in March for the installation of SkyVision, a new full-dome video technology. The Planetarium will reopen on April 5.

Except where noted, no tickets or reservations are required. To find out more, visit www.nasm.edu or call the Smithsonian Information line at (202) 357-2700; TTY (202) 357-1729.

Back in the Saddle



CAROLINE SHEEN

Her Super Cub provides Debbie Gary a leisurely break from airshow flying.

Zipped into my Nomex flightsuit and squeezed into the narrow cockpit of the Bud Light BD-5J Microjet, I taxi past the custom-built Oreck Cyclone, the Fuji Film Sukhoi Su-31, and the Toyota Special Extra 300. It is Friday, a practice day for tomorrow's airshow at Carswell Air Force Base at Fort Worth, but the flightline fence is a wall of spectators. The crests of tents and trucks, displays and concession stands float above them.

Some faces peer upward at the Fina Extra 300L hanging over the runway on the edge of a stall. Others stare at me, sitting on the taxiway. This funny little jet looks like a 12-foot shotgun shell with straight wings and a sloping canopy, balanced on wheels the size of teacup saucers and legs the length of a heron's shins. Inside I slouch like I'm in a lawn chair, feet on the rudder pedals, elbows on the armrests, left hand on the throttle and right one on the control stick.

While Jan Collmer flies the Fina Extra,

a nimble monoplane, I run through my checklist and check my wing tanks. Fuel has already shifted from the right tank to the left while the airplane sat on the ramp, so I turn the right one off to get the tanks back in balance. A lot has changed since I first flew this jet in 1975 on the Bede Jet Team: the fuel system, the engine, the wings, and me.

Back then I was a young hotshot, a full-time airshow pilot, fresh from the Carling Aerobatic Team in Canada. Even though I had stumbled into the airshow world in 1971 like Alice falling down the rabbit hole into Wonderland, I was totally at home in it. I loved everything about airshows: the travel, the airplanes, the smoke oil, the crowds, the press, and the pilots. Most of all, I loved the feeling of maneuvering so low over the runway with such focus that I became the airplane. I was fearless, I was home, and I radiated such joy that everyone on the ground seemed to feel it with me.

I thought I could never lose that feeling,

but I did. Marriage, motherhood, and life on the ground splintered my focus, and airshows stopped being fun. But the memories of them lingered. And after 16 years, I am back.

Collmer finishes his last pass and I latch my canopy. I am uneasy and a little distracted. Practice day used to belong to the pilots. It was our time to get the lay of the land—turnaround points, obstructions on the airfield, the line of the runways. It was time to get your rhythm, to make mistakes, to knock the rust off. But there are a zillion people on the ramp, and I feel like I've slept through the day.

I ignore the static in my brain, add full throttle, and trundle down the runway. Nose up; lift off. Nose level; gear up; smoke on. Accelerate; nose up; a flick of the wrist and roll. Smoke off; turn and climb. I ignore the crowd and look at the airport as if it were a diagram.

My first airshow was in Saint Croix, in the U.S. Virgin Islands, in 1969. I was a glider instructor, soaring, banking, and landing, balancing on a single wheel, and coasting back to the crowd. All the aerobatic performers flew Citabrias, most of them in the one that towed our gliders. Even Mac McGregor, the Federal Aviation Administration monitor and inspector for the whole Caribbean, flew a Citabria in the show. But the luminary, the star who island-hopped from Florida, was Jim Holland. He flew his Citabria like a rodeo cowboy on a bucking bronco, with snap rolls, an inverted ribbon cut, and outside loops that made dust fly off the runway.

Afterward I found him leaning on the flank of his airplane surrounded by frenzied island girls luring him out on boat rides and fishing trips. We talked about flying and I told him to visit my boss, John Macone, and me in Vermont at Sugarbush, our summer base.

When he came by, two years later, I was teaching glider flying in California, but he and Macone concocted a scheme and phoned me. "Hey, Jim Holland is here and he wants you to teach aerobatics for him," Macone said. I didn't even know how to aileron roll. Then Holland said, "I

was thinking of doing a dual act and thought a woman would be a big draw. We're doing a show here in Vermont a month from now. You interested?"

The first time I rode through aerobatics in close formation with Holland, I held my breath. The other Citabria, flown by another of Holland's students, was so big it filled the windscreens. It was months before we had two airplanes of our own and Holland could train me in formation flying, but right away he taught me airshow aerobatics, up high for the first 30 minutes, right above the runway for the last five.

"When you are down low, you never rush," he said. "You float the loop and round out the back, just like you do up high. If you rush, the plane stalls and hits the ground." I wrote down everything he said and studied it at night. When we got to inverted flight I spent part of every day hanging upside down rehearsing inverted turns. "Don't think too much," he warned. "Practice until there is no thought. There is no time to figure things out when you are seconds from the ground."

Thoughts can be like static on the radio. I practiced until I replaced thought with pictures, and that is how I became the airplane.

Today in Fort Worth, I am not being the airplane. Something is sitting on my right shoulder like a backseat driver and I am trying to shrug it off. Still, I go through my routine, while on the ground Bill Beardsley has the mike.

He is my link with the crowd, my DJ, the orchestra leader, directing eyes left or right, up or down. Inside the cockpit I follow the maneuvers I have drawn. On the ground he names them. Light my Fire: I angle my jet off the end of the crowd line, pull vertically, half roll, then pull, arching the nose to point my tail away from the crowd. Then I lift a rocker cover on the panel, toggle a switch, and—pop—a tiny flaming red flare shoots from a belly pod. Down, then up again level for a snap on top of a loop called the Pretzel Basket; a six-point roll, the Six Pack; a rectangular loop, the Frosty Mug; a slow pass with the gear popping in and out, the Tap Dance on the Long Bar.

In the 1970s only a few of us had

The starter screams like an approaching fire truck, then WHOOSH, BOOM, kerosene explodes in the burner can and the engine comes back to life.

miniature museum, and rides for the kids. Airshows are big business now.

I'm almost finished with my practice show when the jet flames out. I had pulled up for Down the Hatch, rolled on a vertical line, held it, throttled back, steady on the stick, and waited. The jet slid backward, then suddenly, violently, it whipped forward and swapped ends. On the down line I added power, but the engine choked, barked twice, then died.

For a second my mind jumps backward 23 years to Mojave, California, the last place I flamed out during a show. I check my memory to see what I did then, and my mind is like a computer loading software. Then suddenly I am back in the present. Fuel: Right tank is off. Wings are out of balance. Fuel on, switches off, then on again, starter button pushed. The igniters tick, tick, tick like a time bomb. The starter screams like an approaching fire truck, then WHOOSH, BOOM, kerosene explodes in the burner can and the engine comes back to life.

I do a wingover back to finish with an inverted pass. On the outside, every airshow is different, but in the cockpit they are all the same. My shows will get better as I polish the rough edges, but already I am home again.

—Debbie Gary

sponsors. Mine were Carling Breweries, Bede Aircraft, and Bellanca Aircraft. Airshows were like folk art: simple but fun. All the action was on the runway side of the crowd line. We flew; they watched. Often I looked at the space behind the crowd and thought, *They need some good food, or some rides for the kids, or something to buy.* There was nothing but hot dogs and soft drinks.

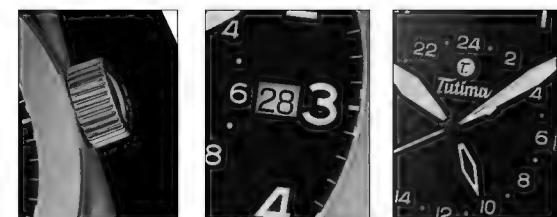
I wasn't the only one thinking that. One day corporate America woke up, rubbed its eyes, and bought a ticket. Airshows are now where the Mall of America meets the state fair—with airplanes. There are still some Mom-and-

Pop shows with local acts and little commercialism, but mostly airshows are enormous flying parties brought to you by our sponsors. Companies like Red Baron Pizza arrive with a first-rate announcer, four glittering Stearmans, and an 18-wheeler packed with food, a

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The Fifty-Cent Classic

As toys go, they are unequivocally low-tech. No computer chips. No multiple functions. Just a few strips of balsa wood fitted together to form a fuselage, wings, and tail. The fancy versions have shiny red propellers with matching wheels. Sold by the millions, these ready-to-fly gliders and rubber-band-powered airplanes have captured the imaginations of generations of children (and plenty of adults). That thrill has kept the Guillow company of Wakefield, Massachusetts, in business for 75 years.

In 1926, Paul K. Guillow, a former U.S. Navy ensign and World War I pilot, created a line of kits for balsa models of World War I aircraft such as the Thomas Morse Scout, Fokker D.VII, and Sopwith Camel. Working out of his suburban Boston garage, Guillow sold the kits for 10 cents apiece.

The following year, Charles Lindbergh made the first solo flight across the Atlantic, and Guillow's products were suddenly in demand.

Soon after, Guillow designed a line of balsa flying model construction kits—scale models built from a wood frame, then covered with light tissue stiffened with a substance called dope. These stick-and-tissue kits included pre-cut strips and blocks, detailed instructions, and pre-formed parts and decals. The modeler provided the tools, the dope, and the patience. When completed, the models were technically airworthy, able to be hand-launched or flown using a small gas engine or a rubber-band-powered propeller, but since one rough landing was likely to ruin as much as 40 hours of work, most ended up on a shelf.

The Guillow company

added Spitfires, Messerschmitts, Zeros, Piper Cubs, and Cessnas. From Guillow's garage, the company expanded to a more suitable building nearby. For years, Guillow was able to make a living by designing and producing such kits (most of which the company continues to make, despite a dwindling market for them), but it was the introduction of his ready-to-fly gliders and rubber-band-powered toy airplanes that made the business take off. Sold all over the world, they are now the company's bread and butter, says president Al

Smith. His father, Alson Earl Smith, started at Guillow's in the 1930s as a model designer, eventually taking over the day-to-day running of the company after the death of Paul Guillow in 1951. Smith was named president in 1990.

Guillow's now makes more than \$5 million a year, Smith says, and has bought out its domestic competitors, Comet of Chicago and Tiger in

Los Angeles. It has expanded its product line but never strayed from its core business: flying models and toys. The Guillow family still retains ownership, and the company retains the atmosphere of a mom-and-pop operation. Nestled in low-slung buildings in an industrial section of Wakefield, the company makes its products pretty much the way it always has. The balsa is shipped from farms in Ecuador, then milled and cut into small strips. Most of the manufacturing is still done with 1940s-

era machinery. It's labor-intensive, admits Smith, who oversees about 60 employees, many of whom have worked for the company for decades.

Because it is lightweight, balsa is perfect for flying, but it is also fragile, as many a disappointed youngster has learned. Take Robert Higgins, who wrote the company in 1959 after his Guillow airplane came to grief: "I have bought one of your fifty cent planes, and it broke as soon as it left the ground. If you don't make your rotten fifty cent plane better, my friends & I won't buy your planes anymore. I think you have the lousiest planes from the lousiest wood (please take this as an insult): drop dead."

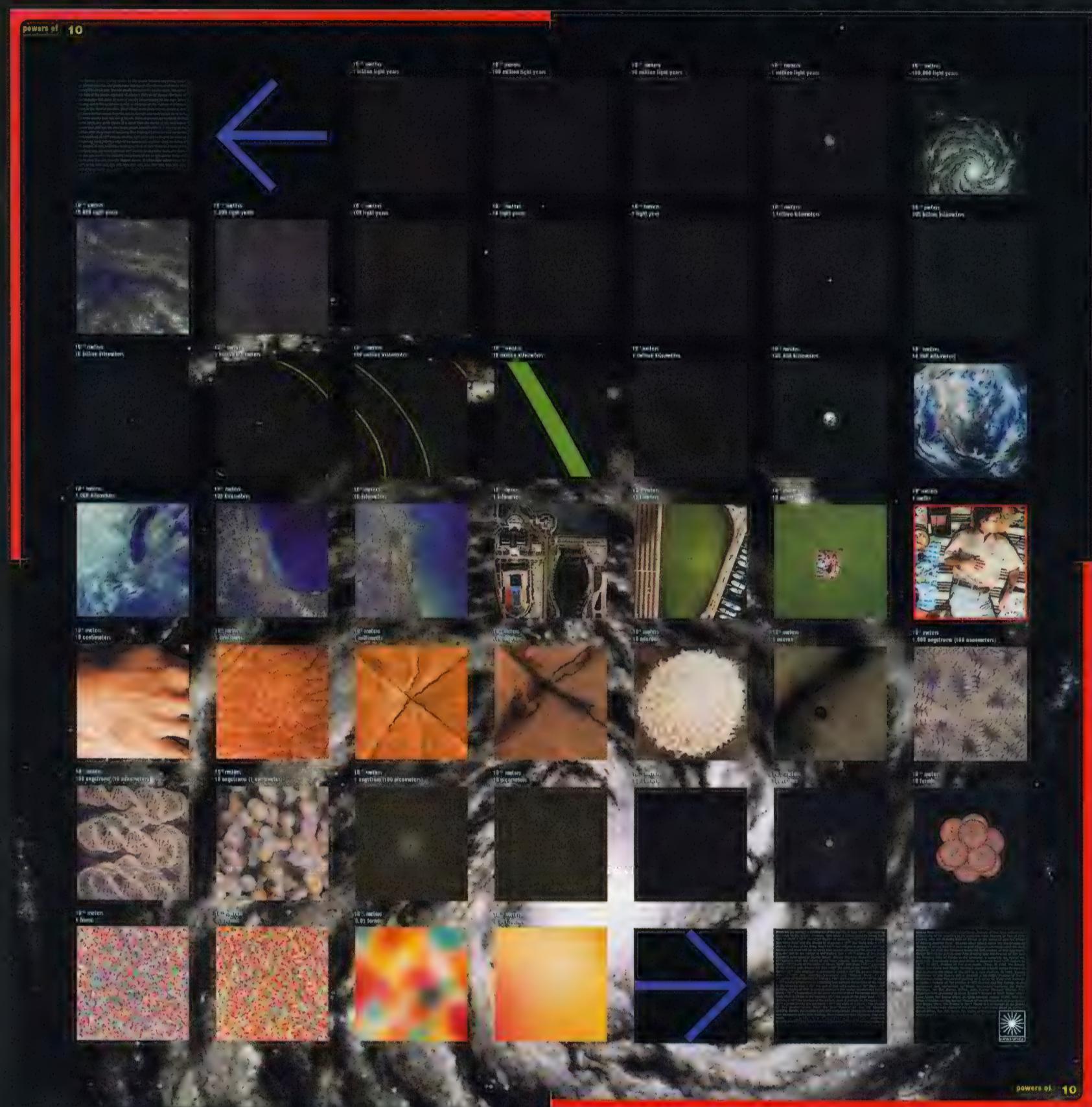
To Robert Higgins, wherever he is now, Smith answers that the company tried to address the durability issue. One employee tried shellacking the wings to temper them. The wings didn't break, but the airplane didn't fly—too heavy. The company has also experimented with Styrofoam and expanded polystyrene, and even looked at vacuum-formed kits. But these solutions added greatly to the cost, and the aircraft ended up breaking as often as balsa did.

Despite the frustrations of Higgins and others, despite the onslaught of video games, computers, and whatever the latest toy fad happens to be,

Guillow's airplanes have found a niche. As the company celebrated its 75th anniversary last year, Smith described the enduring appeal of these simple toys: "My father used to use the term 'a yearning for flight.' That feeling at an airport where you just stop by a window and pause to watch the planes take off. It's just something inside you."

—Tom LeCompte

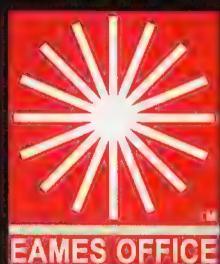
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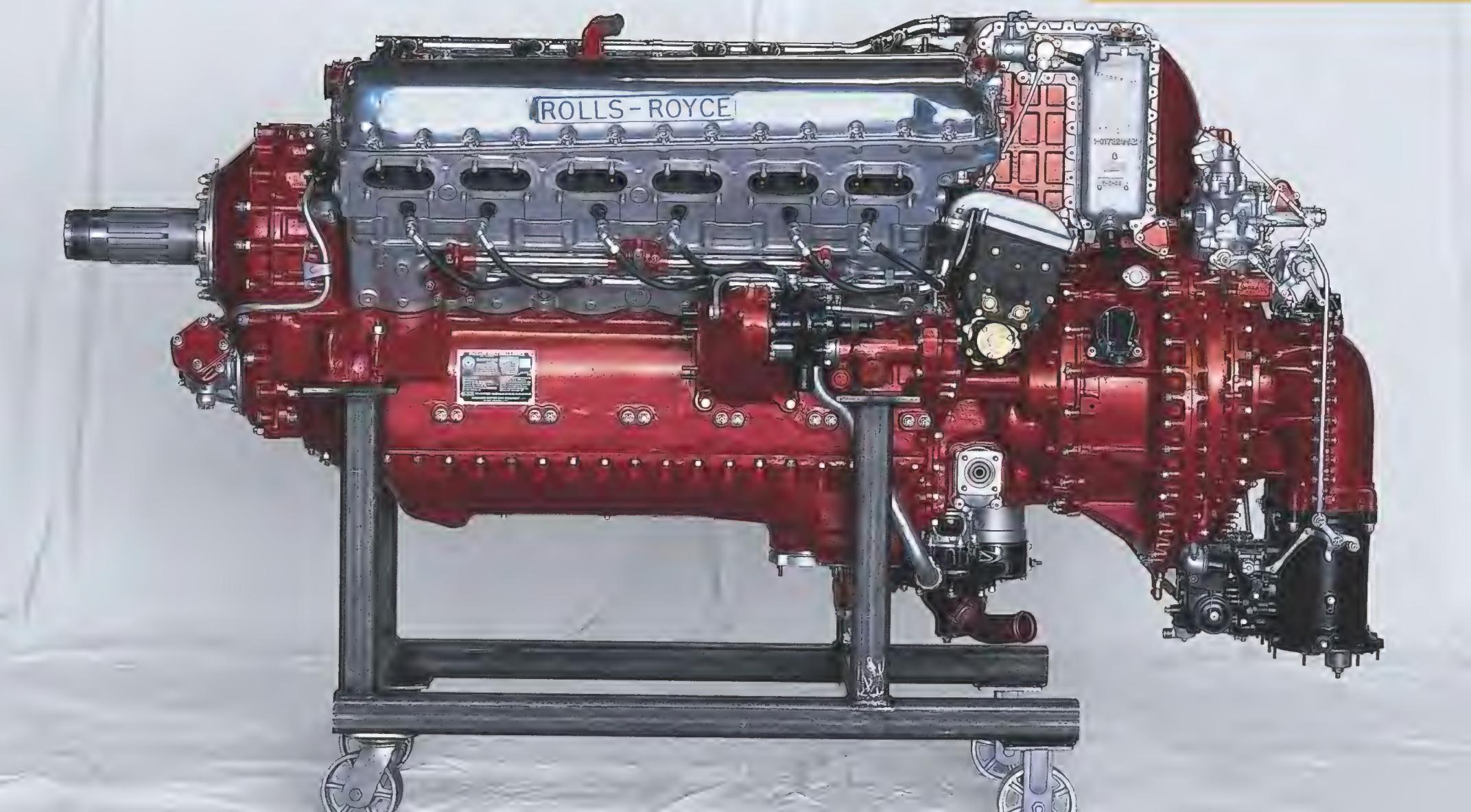


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Masters of the V-12



SIXTY YEARS AGO, THE FASTEST AIRPLANES ON THE PLANET WERE POWERED BY ENORMOUS, COMPLEX V-12 PISTON ENGINES MADE BY ROLLS-ROYCE, ALLISON, AND DAIMLER-BENZ. SIXTY YEARS LATER, SOME OF THE VERY SAME ENGINES ARE STILL RUNNING, POWERING WEEKEND WARBIRDS, MUSEUM ARTIFACTS, AND RENO RACERS. ONLY A FEW MECHANICS IN THE UNITED STATES HAVE THE KNOWLEDGE, SKILLS, EQUIPMENT, AND TEMPERAMENT TO KEEP THEM FLYING. THESE ARE SOME OF THEM.

V-12



The Junkyard Cats

CENTER: MASA SEYA; OPPOSITE TOP: PETER MCBRIDE; BOTTOM: CHAD SLATTERY

Follow a two-lane road running from Nowhere to Nevermind until you're just east of Gilroy, California, and there, down an unmarked dirt road, is Dwight Thorn's company: Mystery Aire Ltd. From this collection of ramshackle industrial sheds emerge the most powerful, reliable, and admired Merlin V-12 air-racing engines in the world. Engine blocks and parts are everywhere. Scarred junkyard cats sun themselves atop pallets of superchargers. Cylinder heads are stacked like cordwood. Every sump and valve cover is filled with eucalyptus leaves and spider nests. Crankcases are slowly sinking into the sandy soil—ashes to ashes, aluminum to aluminum.

How he works miracles in such a setting may be a mystery, but make no mistake: Dwight Thorn builds awesome engines that routinely win races. Looking a bit like Wilfred Brimley in bib overalls, the white-haired, 64-year-old Thorn is putting the finishing touches on a bright red Merlin with mirror-polished aluminum valve covers that will soon fill

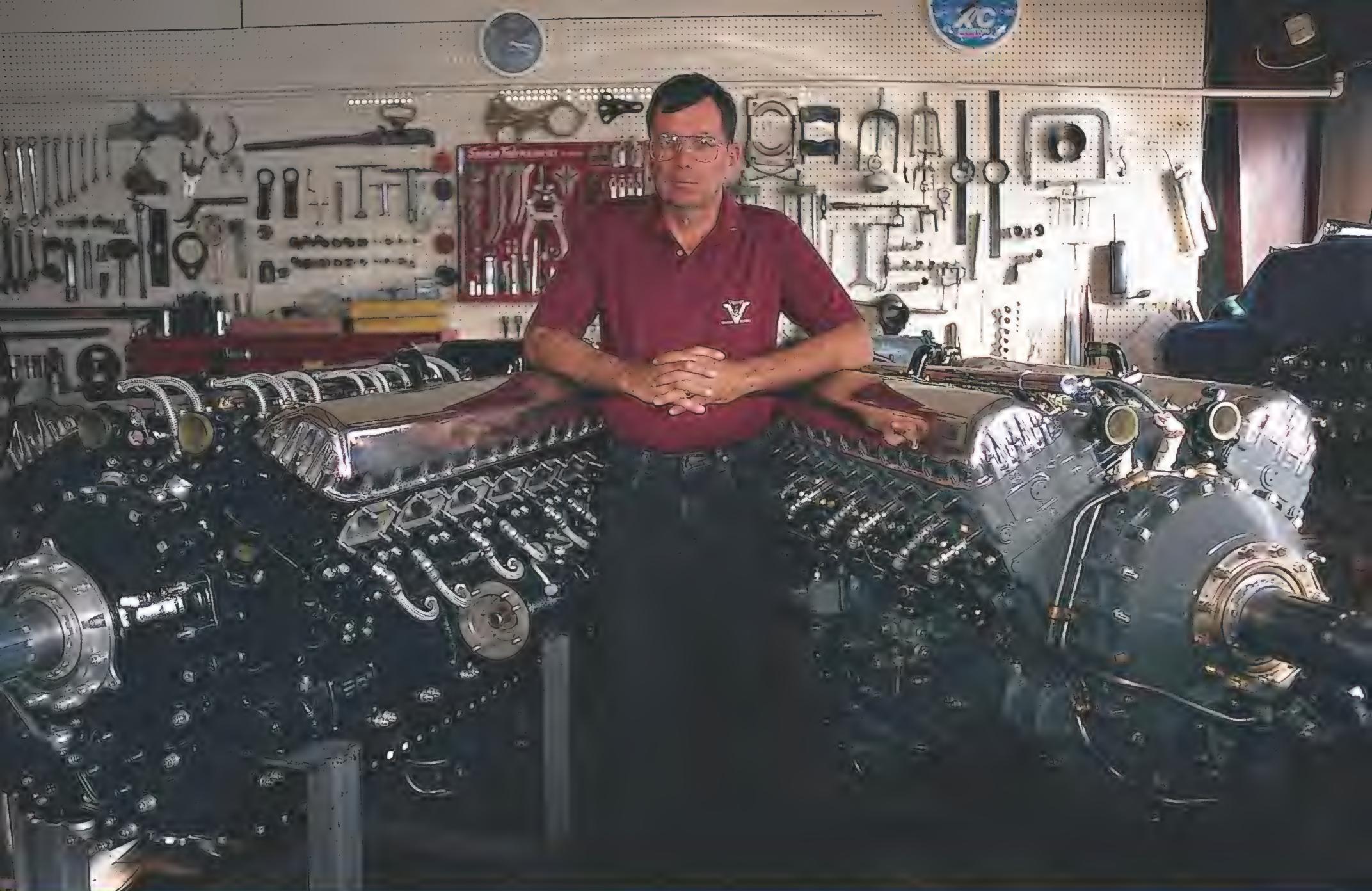
Dwight Thorn's casual get-up (opposite, top) belies a reputation as a premier rebuilder of Rolls-Royce Merlins (opposite), used by P-51 Unlimited racers (above).

BY STEPHAN WILKINSON

the snout of the two-seat TF-51 *Crazy Horse*, a Mustang that flies riders for a fee in Florida. Seventy-five percent of his work is overhauls of stock engines like this one. "But the two or three racing engines we do every year take just as long as all the others put together," he says. Thorn charges \$60,000 to \$80,000 for an overhaul, depending on the condition of the run-out engine, and \$160,000 to \$180,000—and up—for a labor-intensive, 3,500-horsepower racing motor.

Exactly what do you do to hop up a Merlin? "Simple," Thorn says with a grin. "Disconnect the boost [limiting] control. We've seen 150 inches of boost, which is where the gauge stops. And which is probably just as well."

Most of us accustomed to more conventional motorsports assume that "tuning" separates the prime V-12 builders from the also-rans. Tuning means "porting and polishing" the intake manifold passageways to improve the flow of the air-fuel mixture, "boring and stroking" to increase the engine's working volume, "bench-flowing and blueprinting" to ensure that the cylinders' mechanical dimensions match—all that plus tinkering with spark timing and tuning exhaust pipes to boost evacuation of the combustion gases must be a large part of successful air-race engine building, right?



Nope. The category in which the V-12 engines run at Reno is called Unlimited, and the rules basically say the engines must reciprocate and turn propellers. There is no size limit, no rule against performance-enhancing devices such as turbochargers, superchargers, nitrous oxide injectors, designer fuel, exotic materials, or weight-saving techniques.

As a result, the top V-12 builders put their engines together using the strongest possible parts, reinforcing weak areas (such as the Merlin's relatively vulnerable crankcase), and carefully assembling and torquing each and every nut and bolt, but with normal, stock profiles and settings for the camshafts, valves, and ignition.

And then they turn up the boost. The more air and fuel the supercharger can cram into the engine, the more horsepower it makes. But the higher the boost, the stronger the engine must be to withstand the unholy pressures inside the cylinder.

Thorn's specialty is replacing Rolls-Royce rods with beefy, never-run Allison connecting rods and adapting them to fit Merlin crankshafts and pistons.

This allows the engine to operate at 135 inches of supercharger pressure but at lower rpm because of the rods' greater mass. Before Thorn's imaginative fix, racing Merlins with their lighter connecting rods turned as much as 3,800 rpm, the propeller spinning so fast the blade tips were supersonic, which meant they weren't creating thrust.

Now racers can back the revs down to 3,300 or 3,400, allowing the prop to get a better bite but sending cylinder pressures into the stratosphere.

Most of Mystery Aire's clients aren't racers. "We're dealing with a different kind of customer now," Thorn says. "Back in the 1960s and '70s, the majority of the owners worked on their airplanes, had military experience, some had even flown the P-51 in the service. Today it's the *nouveau riche*. They're like the Ferrari guys—people who've bought something they assume will appreciate in value."

Between Rolls-Royce, Packard, and Ford of England, 165,000 Merlin engines were made during and after World War II—second only to the approximately 178,000 R-1830 Twin Wasps turned out by Pratt & Whitney and its licensees. Today, enough Merlin parts survive to make perhaps a few thousand. In the '60s, acres of Los Angeles were carpeted with Merlins and Allisons owned by a speculator who had

Mike Nixon (opposite, top) never advertises, and doesn't need to. In the circle of P-51 owners like Tom Wood (opposite), all engine builders are household names.

**TINKERING WITH SPARK
TIMING AND TUNING
EXHAUST PIPES MUST
BE A LARGE PART OF
SUCCESSFUL AIR-RACE
ENGINE BUILDING, RIGHT?
NOPE.**

bought them for pennies a pound. When land prices shot up the engines were sent to Japan, melted, and recycled.

Thorn's best engines are built with what the *cognoscenti* call "transport banks." Between 1948 and '50, Rolls-Royce turned out the strongest and most durable Merlins ever for Canadair-built Douglas DC-4s known as Northstars. These 1,760-horsepower engines could pound away for hours without missing a beat, and they made use of every trick Rolls had learned about building durable V-12s. They are the gold standard, and if you want a racer, they are what you need.

What about nitrous oxide? The Luftwaffe used it to augment its simple, single-stage superchargers, and hot-rodders inject it for instant acceleration. (NOX is a powerful oxidizer that "thickens" the air—and therefore the amount of fuel—that an engine can inhale.) Thorn will provide nitrous if asked but says, "It's hard to carry enough to make it worthwhile. A hot-rodder can fit a five-gallon tank and go play all night, but with an engine this size, you've got to have a lot on board."

Scattered throughout Thorn's warren of shops are shelves, boxes, racks, and pallets of Merlin parts, many still in sealed Rolls or Packard packaging.

"I've been able to buy a couple of complete [shop] inventories over the years," he says. "I could probably build 20 complete engines from scratch. Not counting the things that wear out, like bearings, I probably have 200 engines' worth. But someday there will be one little widget that nobody has anymore, and you won't be able to finish

The Masters know how to work on radials too, but the V-12 business has greater cachet.

an engine unless somebody steps up to the plate and manufactures it." Part of the problem, Thorn points out, is that a Merlin has six times as many parts as an Allison. "I blame it on socialism," he says. "The more parts they had to make, the more hours of labor were needed and the more make-work the government achieved."

Thorn's protégé, Mike Barrow, builds his own engines alongside Thorn and pitches in to help when needed. When Thorn retires, it's likely that Barrow will take over the business. "I had a cousin, Louis Norley, who was an ace with the Fourth Fighter Group," Barrow says. "I've always had a thing about P-51s and Merlins. It's neat to be able to work with this stuff, and I like the air racing too. I've been a crew chief, though when you're both the crew chief and the engine guy, no matter what breaks you're in trouble," he says with a grin.

"People my age—I'm 40—when I tell them that I overhaul Rolls-Royce V-12s for a living, they don't know what I'm talking about."



ERIK HILDEBRANDT

Stealth Shop

Tehachapi, California, is a small, high-desert town, but when I ask for directions to Vintage V-12s, nobody knows what I'm talking about. Mike Nixon, a scholarly, preoccupied-looking man who wouldn't look out of place on the campus of Caltech, likes it that way. "I don't do any advertising, and I let the local paper do a story on us once every four years as long as they don't print where we are. It would only attract the tire-kickers."

At one point while I'm in Nixon's compulsively neat shop, a deliveryman from town shows up and takes in the spectacle of a dozen or more glossy V-12s. "What are they for?" he asks, wide-eyed. For airplanes like those in the pictures on the walls, Nixon explains. "You mean for, like, hobbyists?" Well, something like that.

Nixon's "hobbyists" are, for the most part, serious restorers rather than racers. "I can do a restoration engine and see it come back for an over-haul in six or seven years," he says. "Racers fly your engine for two or three years and blow it up. See that yellow supercharger and set of valve covers?" he asks, pointing to a rack of Merlin parts. "They're from an engine I first worked on in 1978, and it's on its fourth owner since then."

Nixon knows he can't hand-pick his customers, but he does steer clear of some. He recalls the guy who bought a P-51 and called for some engine operating tips. "I was on the phone for 15 minutes and couldn't get a word in edgewise," he recalls. "I hung up and said, 'He's dead in a month.' I was right: He flew into a hill while doing a low-level inverted pass."

Until recently, Nixon specialized in all-out racing engines that compete in the Gold races, but he burned out on the serious competition. Besides, he says, "It's far better for us to have four or five guys who fly our engines in the Silver and Bronze races [at least in part contested by basically stock, authentic warbirds] at Reno, have a great time, and tell everybody about it than it would be for us to win the Gold. Or, worse, be leading the Gold and scatter an engine. It takes years to get over something like that."

Nixon knows that well. He says the race business peaked in 1982, when he built the engines for four of the seven finalists at Reno and *Dago Red* won with one of his engines. "We were overwhelmed with work after that," he says. But such reputations, if not easy come, are certainly easy go. Several of his race engines blew during a subsequent season, due to problems he traced back to a piston-ring sup-

plier, and the gossip mill began to grind. "The only Gold racer I'd have any interest in now would be a Griffon-powered airplane, because it would be a challenge and because there's so much Griffon stuff available," Nixon says.

Many people think the Merlin was a spinoff of Rolls-Royce's Type R racing engine, which powered the Supermarine Schneider Cup floatplanes. But the 1,650-cubic-inch Merlin was derived from the 1927 Kestrel V-12; the 2,240-cubic-inch Griffon was the production version of the big R. Development of the Griffon was put aside when the Hurricane and Spitfire needed a smaller, lighter engine.

When Germany attacked England with V-1s, Rolls shoehorned Griffons into what became amazingly fast, low-level Spitfires designed to run down the jet-powered flying bombs. After the war, Griffons powered the four-engine Avro Shackleton maritime patrol bomber. Hundreds survive, having led a sweet life of low-power, low-level loitering. There are even Griffon "box engines" available, still in crates after being overhauled by Rolls-Royce.

Vintage V-12s has accumulated a considerable stock of Griffon parts, but what Nixon is proudest of

is his selection of "early-engine stuff." With almost 150 P-51Ds flying, along with a considerable number of late-model Spitfires, restorers are today embarking on more interesting projects. And if you want to do an A-36 Mustang with its original Allison, a long-nose P-40, or a late-'30s Spitfire, you may need to come to Nixon for the parts. He guesses that his trove's value is at least "a couple



ERIK HILDEBRANDT

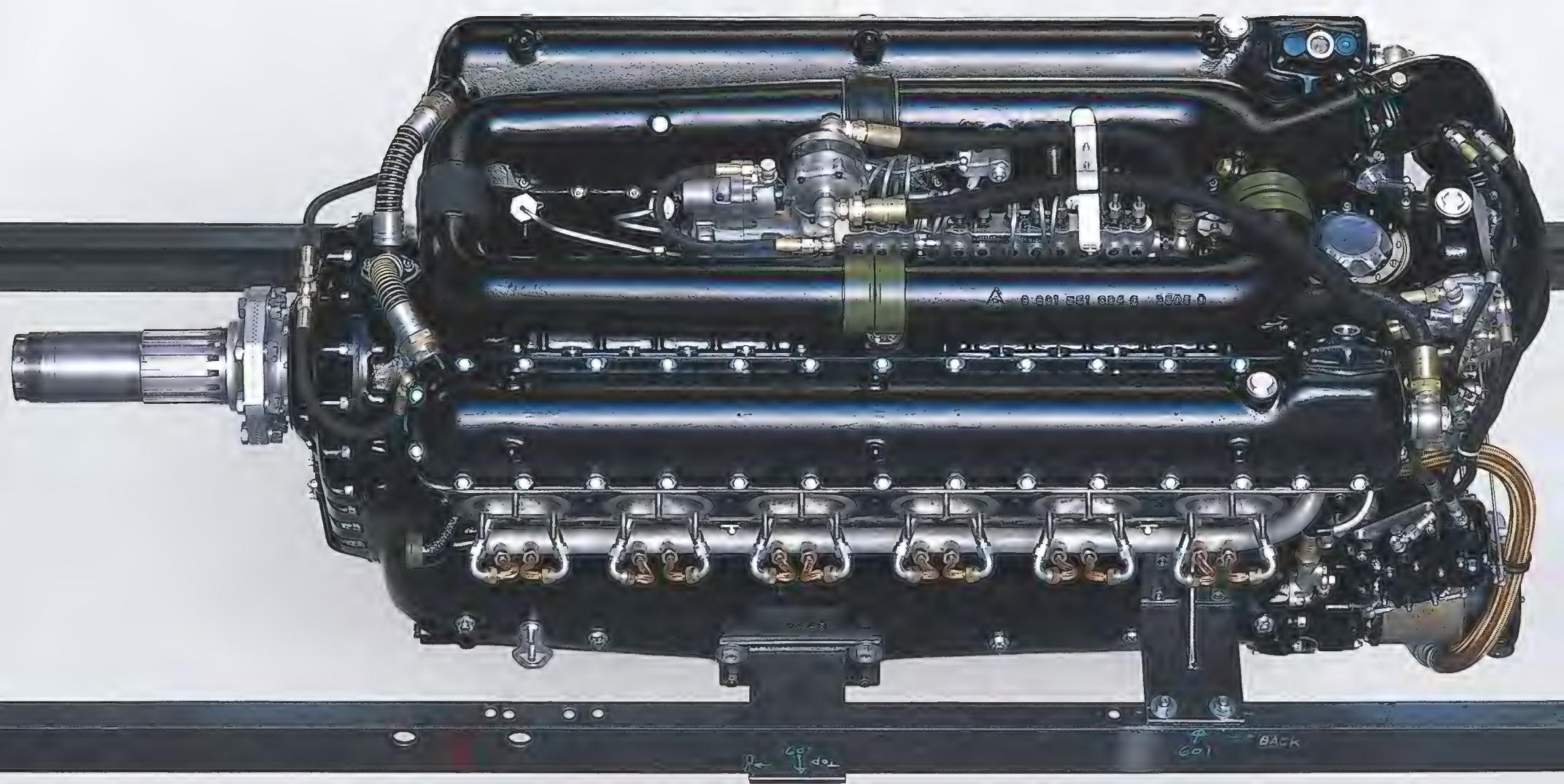
Bill Moja prefers Allisons. English engines, he says, have "way too many pieces."

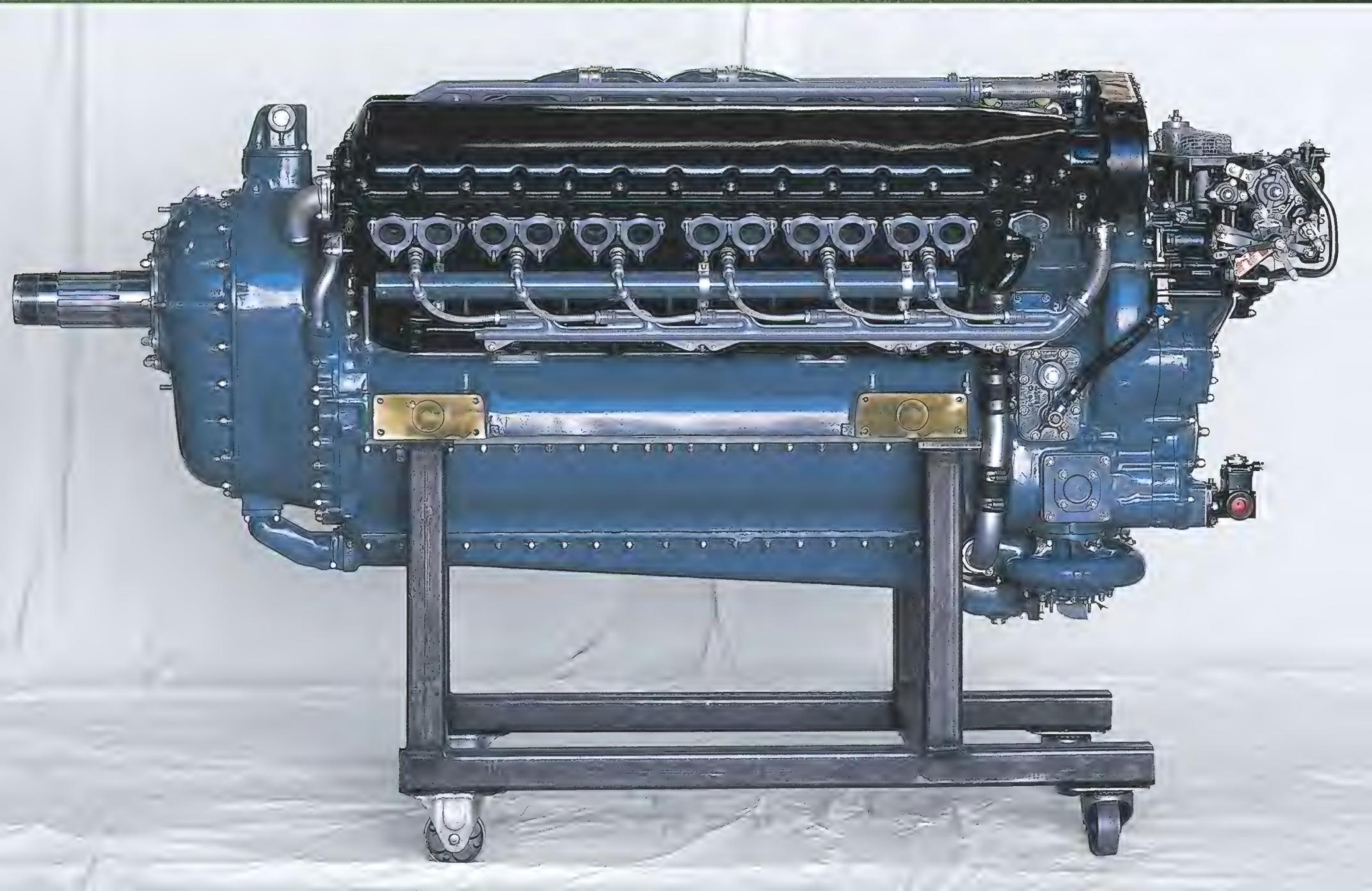
million," but who can put a price tag on racks of prop reduction gears that look big enough to fit a ship's engine or a box of thousands of tiny lock-tab washers in an English Whitworth standard size that no longer exists?

Nixon's most recent project has been the restoration of a rare Daimler-Benz DB 601 inverted V-12 for a New Zealand collector's Messerschmitt Bf 109E. "The biggest problem has been all the magnesium parts—intake manifolds, valve covers, accessory cases, things like that," he says. "Since they're all down at the bottom of the engine when it's mounted in the inverted position, moisture gets at them and they corrode away."

Nixon points to the engine's original valve covers, amid a shelf of equally useless DB 601 parts. They are magnesium doilies that are filligreed with rot, which is why it took

Sam Torvik (opposite, top) rebuilt a BMW radial and says German technology was "far ahead of ours." Nixon parted out three engines to build one DB 601 (opposite).





parts from two donor 601s to complete the job. He also had to have a propeller reduction gear cover, a casting about the size and shape of a bedpan, manufactured. "Pattern, casting, and machine work, it cost \$20,000," he says. "I look at that and laugh when people suggest building an entire new Merlin. It would cost \$1 million per engine, easy." The rebuilt DB 601 will cost its owner nearly \$300,000, plus \$100,000 for the original core and the extra engines bought for parts, but then Nixon has put a year and a half into the job. It's the second 601 he's done; the first one took over three years.

The German, American, and British V-12s are fairly similar in general, but Nixon says the complexity of the DB 601 is obvious. "The British and Americans did more in-the-field maintenance, whereas the Germans would just send the whole engine back to the factory. They could change the engine in a Messerschmitt in a little over an hour." And that's why you see World War II photos of shirtless, oil-covered GIs pulling cylinders and replacing pistons. The Germans left that work to men in white shopcoats.

"Still, there were very few people either at Rolls, Allison, or Daimler-Benz who knew the whole engine," Nixon says as he recalls the roots of his profession. "Almost everybody was a specialist. It was only in the 1950s and '60s that we evolved to generalists who actually work on the whole engine—guys like Dwight Thorn and me and a few others who have basically had to learn the whole engine."

Is Nixon's business growing as warbirding increasingly becomes the sport of kings? "'Stable' is a better word for it," he says. "We've had some huge incremental increases, like when in the late '70s a lot of ex-South American airplanes became available, and then in the late '80s when all the Spitfire gate guardians came down to be made flyable for the 50th anniversary of the Battle of Britain, but I don't think there are any more 'secret' warbirds out there anymore. The legendary 50 P-51s that were supposedly in China turned out to be nonexistent. When the Berlin Wall came down, that was the last time a large group of World War II aircraft suddenly became available."

"But the nice thing for us is that when you restore an airplane, you never see it again. When you restore an engine, it comes back for an overhaul every six or 10 years."

Allisons (opposite) powered P-38s and P-40s (opposite, top), but lacked the Merlin's mystique. During World War II, Allisons could be repaired in the field by GIs.

WHAT DO YOU DO TO HOP UP A MERLIN? "SIMPLE," SAYS DWIGHT THORN. "DISCONNECT THE BOOST CONTROL. WE'VE SEEN 150 INCHES OF BOOST, WHICH IS WHERE THE GAUGE STOPS."

The Odd Couple

Sam Torvik and Bill Moja have worked together for 30 years and still argue about whether the shop radio is too loud. Torvik is small, tightly wound, and wears a trimmed beard. He's the Merlin specialist. Moja is a big, shuffling, mustachioed galoot, the kind of man whose shirttails are usually out. He prefers Allisons. "The English engines....," he shakes his head. "Full of lousy rubber seals and way too many pieces. They're like Jaguars burning out at the side of the road all the time. I don't know why we're still doing Merlins. There's so much labor in 'em."

Torvik and Moja are the V-12 masters at JRS Enterprises, which is housed in an old brick building next to some automobile dealers in suburban Minneapolis. The "R" has fallen off the JRS sign, and a constant stream of traffic rumbles past on a four-lane highway. This was once the hobby shop of racer John Sandberg, who was killed in 1991 in his remarkable homebuilt Unlimited racer *Tsunami*, a mini-Mustang that was the smallest airplane ever to have carried

a Merlin. Today, JRS Enterprises is basically a fabrication shop fulfilling small contracts for the aerospace industry, but the engine building continues almost as though nobody knows how to stop it.

"Why are we still doing this? Because we always have," Moja says. "Nobody's making much of a living doing this stuff, because it's just for rich boys and their toys—that and flying museums. But it's warm in

here during the winter, and you get to go home at 3:30." Torvik is happiest left to himself. He has his own small engine assembly area, where he's finishing up an early Merlin that will go to a collector in England. (Early Merlins and Allisons are far rarer than the later more powerful and sophisticated variants.) "I don't know what it's going into, either a Spitfire or a Hurricane," Torvik says.

He is impressed by what he's seen of German World War II engines, having recently worked on a BMW radial from a Focke-Wulf Fw 190 fighter. "Their technology was so far ahead of ours at the time, it was easy to see," he says. Moja demurs, of course. "They were *way* too complicated," he says. "You didn't have to be a rocket scientist to work on an Allison."

Amid piles of engine parts and tools, Moja is building an Allison for a P-40 restoration. Hanging on a wall nearby are a huge Merlin connecting rod bent a good 10 degrees from straight and a supercharger impeller that looks as though somebody had punished every blade with a hammer. They're



PETER MCBRIDE

Mike Barrow works with Thorn and represents a younger generation of V-12 specialists.

from *Tsunami*'s Merlin, and they show what happens when an anti-detonation injection system fails. "If the ADI system fails, you can't reach anything in the cockpit fast enough to keep the engine from blowing up," Mystery Aire's Mike Barrow had told me, and this display proves it. The explosion nearly blew *Tsunami*'s cowling off.

JRS does 15 or so engines a year, most of them radials for collectors and restorers and a few commercial operators. They do only one or two V-12s a year but are usually at work on several at a time while they wait for overdue supplies or missing parts. "The commercial stuff, that's a push, because those people *need* their engines," Moja says. "A V-12, the worst that happens is a rich boy misses an airshow. We haven't worked on a weekend since September '91." Which, as it happens, is when Sandberg died and JRS was out of the air-racing business.

"The round motors are probably more reliable than the V-12s," Moja admits, "but remember, the V-12s were made for an entirely different purpose.

[The radials] were the truck engines, hauling bombs for the most part. The V-12s were the hot rods, made to go balls-out all the time. You're asking me to fly behind it? I'll take the radial every time."

A variety of ailments can afflict a V-12 when it's asked to do too much—even Moja's Allisons. They're prone to cylinder-liner distortion if overboosted, because the liners are locked to the block both top and bottom, and when uneven expansion is exacerbated by sudden overheating, the liners deflect slightly and let the combustion charge sneak past the rings. That is invariably fatal to that piston, which destroys the head with its shrapnel. "The Merlin's liners, even though they're thinner, stay pretty much round, because they float at the bottom end, where they're sealed by O-rings," Moja points out.

Imagine a soup can with both its top and bottom cut out and you have a small, very thin cylinder liner. Grab it by each end and twist, and it distorts—becomes slightly oval. Grab it by only one end and you can't do that.

"See that semi out there?" Moja asks, pointing to a battered white trailer outside the shop. "It's filled with cylinder heads that prove you can overboost an Allison." Sandberg began his short air-racing career with an Allison-powered Bell P-63 Kingcobra. An inveterate tinkerer, he continually had its engine modified in a variety of ways, never leaving well enough alone. "We modified and modified that engine and kept blowing it up," Moja says. "Then we finally took it back to stock and it ran better than ever."

"There are no tricks to building a good engine," Sam Torvik says. "Everybody thinks there's magic involved, but there isn't. You just have to build it right and use the best parts. It's becoming harder and harder to find them, though. When you keep blowing these things up racing them, where are you going to get parts for your regular customers?"

Some of the simplest yet most difficult-to-find parts—new crank and rod bearings, for example—would be easy for a competent fabricator to manufacture, "but the people who could do it don't want the liability," Torvik points out. Torvik and Moja blame "the boat people" for the dearth of parts. "When the hydroplane guys found out they could use Merlins and Allisons [for Gold Cup racing], it drove the value of a core from \$250 to \$25,000," Moja says. "And then the tractor-pullers came along. Then when they screwed up all the engines they could find, they went to turbines. If I get a call from a tractor-puller looking for parts, I won't even talk to him."

The heart of a Merlin or Allison engine—"the core"—never wears out, unless the ravages of time simply corrode it

beyond redemption or racing use overstresses it. The crankcase and crankshaft, cylinder banks, accessory case and valve covers, heads and cams, supercharger, propeller reduction gears, and various pumps and fittings are usually salvageable. During a serious rebuild, new pistons, rings, bearings, valves, springs, camshafts and followers go into the core, and the cylinder liners are bored slightly oversize. Sometimes, all



PHILIP MAKANNA

The legendary John Sandberg raced an Allison-powered P-63 Kingcobra like this one.

that's needed are new seals, gaskets, and O-rings. But that won't be enough to help a buyer who has fallen for the bargain price of a former hydroplane engine. The main clue that the engine's been on the water is nonstandard fittings for oil-scavenge pumps at the aft end of each head, which are necessary because the engines sit at an angle in boat-racing. They live a short life turning at very high revs, with the prop jumping in and out of the water, and their cores are useless for anything but...well, boat anchors.

Of course the air racers destroy engines too. "Yeah, but they only do it once a year," Torvik says.

For all these men, building V-12s is not so much a profession as a calling. And the nature of the priesthood is unlikely to draw young airframe-and-powerplant graduates who have airline companies beating down their doors. If the V-12 business weren't turning at least a modest profit, none of these shops could afford to pay the light bill. But you get the feeling it's not about the money. 

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BUILDING A GREAT Air and Space Library

A LIST OF TOP TITLES FROM OUR PANEL OF EXPERTS

The world of flying sometimes seems like a small town where everybody knows or is connected to everybody else—until you're in a library, staring at all the books that have been written about all the people and all the inventions of that world. Then it is populous and vast.

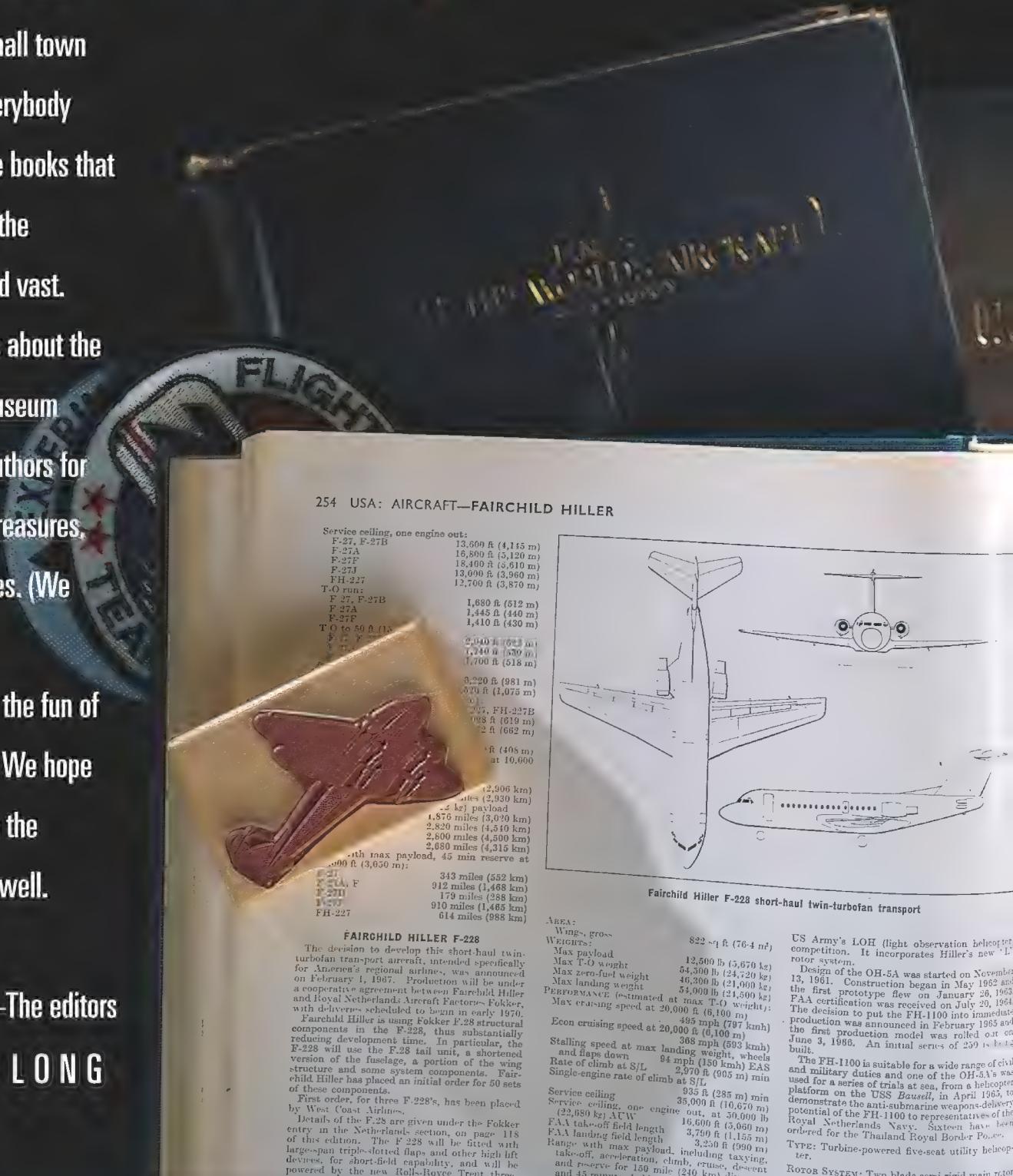
To find in that plenitude the very best books about the world of aviation and spaceflight, we asked museum curators, scholars, historians, journalists, and authors for their recommendations and compiled a list of treasures, both old and recent, from a number of categories. (We also threw in a few of our own favorites.)

Part of the pleasure of reading, of course, is the fun of exchanging strong opinions with other readers. We hope our selection will inspire not only some trips to the bookstore but some passionate discussions as well.

Read on...

—The editors

PHOTOGRAPHS BY ERIC LONG



Reference Books

What year did Louis Blériot cross the English Channel? Which B-17 model had a chin turret? A well-stocked aviation library includes reference books that can provide quick answers to even obscure questions. (We've listed space references in the "Space" section.)

When building a reference library, National Air and Space Museum archivists Brian Nicklas and Dan Hagedorn—who routinely field all manner of aviation queries posed by the public—recommend going from broad to specific. "You

can start a library with general and encyclopedic works first," says Hagedorn. He suggests such titles as **Jane's Encyclopedia of Aviation** (Crescent, 1996) and **The Chronicle of Aviation** (JL International Publishing, 1992); the latter, by renowned aviation writer Bill Gunston, is a year-by-year account of major aviation and space-related events. Hagedorn notes that it has a few errors, but adds, "You can hardly point to a book on aviation that doesn't have them."

For military aircraft, Hagedorn and Nicklas recommend the Putnam Aviation Series books, in particular two by Gordon Swanborough and Peter M. Bowers: **United States Navy Aircraft Since 1911** (Naval Institute Press, 1990) and **U.S. Military Aircraft Since 1909** (Smithsonian Institution Press, 1989), which covers aircraft of the Army, Army

Air Forces, and Air Force. Hagedorn also recommends two works that are out of print but worth the search: John M. Andrade's **U.S. Military Aircraft Description and Serials Since 1909** (Midland Counties, 1997) and Francis Dean's **America's Hundred Thousands** (Schiffer, 1997), an unbeatable guide to World War II fighters. To learn about military aircraft of other nations, try **German Aircraft of the First World War** (by Peter Gray and Owen Thetford, Putnam, 1962), **German Aircraft of the Second World War** (by J.R. Smith and Antony Kay, Putnam, 1972), **Aircraft of the Royal Air Force Since 1918** (by Owen Thetford, Putnam, 1995), and **Japanese Aircraft of the Pacific War** (by René Francillon, Naval Institute Press, 1995).

General-aviation scholars like the nine-volume series **U.S. Civil Aircraft** (Tab Aero, 1993), in which indefatigable researcher Joseph Juptner provides data and photos for 817 non-military U.S. aircraft granted Approved Type Certificates between 1925 and 1957. **Airlife's General Aviation: A Guide to Postwar General Aviation Manufacturers and Their Aircraft** by R.W. Simpson (Airlife Publishing, 1995) gives the production histories and family trees of manufacturers throughout the world.

Fans of research aircraft should check out **Flying the Frontiers: NACA and NASA Experimental Aircraft** by Arthur Pearcey (Airlife, 1993), which lists every aircraft flown at every research center. Also good: Jay Miller's recently updated **X-Planes: X-1 to X-45** (Midland, 2001).

And finally there's the legendary **Jane's All the World's Aircraft** (Jane's), an annual book series describing in exquisite detail every aircraft currently in production or under development.

for operation from water on quick-attach inflatable floats produced by Garrett's Air Cruisers Division.

POWER PLANT: One Allison 250 C16 shaft-turbine engine, with 317 shp available for take-off and normal rating of 270 shp. Single-bladder fuel tank in bottom of centre fuselage, capacity 69 US gallons (261 litres). Refuelling point on starboard side of rear fuselage. Oil capacity 2.75 US quarts (2.6 litres); engine, 2.75 US quarts (2.6 litres) in transmission.

ACCOMMODATION: Pilot and passenger side-by-side in front. Rear seats for three passengers in standard utility model. Four-seat executive layout available. Rear seats fold to provide high cargo deck. Four forward-hinged doors, two on each side of cabin. Baggage compartment under engine deck, capacity 150 lb (68 kg), with door on starboard side.

ELECTRONICS AND EQUIPMENT: Radio optional.

SYSTEMS: Dual hydraulic systems, pressure 900 lb/sq in (63.5 kg/cm²), for cyclic and collective pitch controls. Boost cylinders manufactured by Conair Inc. 28V electrical system, with 100Ah starter/generator and 24Ah battery. Hamilton Standard stability augmentation system to maintain automatically aircraft attitude in pitch and roll.

ARMAMENT: Provision for wide range of weapons, including anti-submarine weapons, or two weapon packs each containing two 7.62-mm machine-guns with 300 rpg or two grenade launchers, or one of each, mounted on each side of cabin.

DIMENSIONS, EXTERNAL: Diameter of main rotor 35 ft 5 in (10.60 m); diameter of tail rotor 6 ft 0 in (1.83 m); length overall, rotors fore and aft 39 ft 9 1/2 in (12.13 m).

Length of fuselage 29 ft 9 1/2 in (9.08 m); width of fuselage 4 ft 3 1/2 in (1.32 m); height overall 9 ft 3 1/2 in (2.83 m); skid track 7 ft 2 1/2 in (2.20 m).

DIMENSIONS, INTERNAL: Cabin: length 7 ft 8 1/2 in (2.35 m); max width 4 ft 2 1/2 in (1.31 m); max height 4 ft 7 in (1.40 m).

AREAS: Main rotor blade (each) 15.08 sq ft (1.40 m²); tail rotor blade (each) 1.02 sq ft (0.095 m²); main rotor disc 981 sq ft (91.14 m²); tail rotor disc 28.27 sq ft (2.63 m²).

WEIGHTS AND LOADING: Weight empty 1,396 lb (633 kg); max T-O weight 2,750 lb (1,247 kg); max disc loading 2.80 lb/sq ft (13.7 kg/m²).

PERFORMANCE (at max T-O weight): max cruising speed at 5,000 ft (1,525 m) 127 mph (204 km/h).



The experience of flight can be so life-altering that it is only natural that it would inspire the writing of autobiographies and memoirs. We have included memoirs throughout the categories of this guide; the following are works that fall outside our divisions.

I Could Never Be So Lucky Again by General James H. "Jimmy" Doolittle (written with Doolittle biographer Carroll V. Glines; Schiffer, 1995). Covers Doolittle's racing, his experiments "flying blind," as he called instrument flying, and his experiences during and after World War II.

Forever Flying by R.A. "Bob" Hoover (written with Mark Shaw; Pocket Books, 1996). The famous airshow pilot recalls, as the book's subtitle promises,

"Fifty Years of High-Flying Adventures, from Barnstorming in Prop Planes to Dogfighting Germans to Testing Supersonic Jets."

Skunk Works by Ben R. Rich and Leo Janos (Little, Brown, 1994). As much a portrait of Lockheed's legendary Skunk Works, which the author eventually headed, as it is an autobiography of Rich.

Burning the Days by James Salter (Random House, 1997). A literary writer recounts his life's story, including his service as an F-86 pilot in the Korean War.

Jet: The Story of a Pioneer by Frank Whittle (Frederick Muller, 1954). The author's fascinating struggle to invent the gas turbine engine.

Aviation's Superstars

In the bountiful realm of aviation biography and autobiography, the best of the lot was written by the man who stood literally head and shoulders above the rest. Charles Lindbergh's **The Spirit of St. Louis** (Charles Scribners, 1953) "is one of the few books written by a celebrity that won and deserved to win the Pulitzer Prize," says A. Scott Berg, whose own biography, **Lindbergh** (G.P. Putnam's Sons, 1998), also won the Pulitzer. "The book was written 25 years after the epic flight," Berg says, "and his passion for aviation and his excitement over what he had done still came through 25 years later.

"He cared so deeply about that book because the book that really hooked a generation of young men into aviation was **We** [written days after his 1927 transatlantic flight], which he never really liked. Lindbergh himself took over the writing of the book from a ghost writer and had to deliver it to Putnam. He was never happy with it. It was the best he could do under the circumstances." At the time, Lindbergh was a 25-year-old college dropout, and he had had to finish the book in just a few weeks.

Berg's biography, destined to become a classic itself, is the only one of the 30-some books published about the aviator to have plumbed the archive of the Lindberghs' unpublished papers, which reside at Yale University. In addition to receiving permission from the pilot's wife, Anne Morrow Lindbergh, to quote from the archive, Berg interviewed her and the Lindbergh children, and that enabled him to present a rich picture of the aviator's life, including his loving but troubled marriage.

Anne Lindbergh, of course, published several landmark memoirs. The two of most interest to aviation-minded readers—**North to the Orient** and **Listen! The Wind**—are both recollections of survey flights the Lindberghs undertook for Pan American Airways. "For me, they are the most vivid and

Memoir & Biography



vibrant of Anne Morrow Lindbergh's writing," says Berg. "I think people who are not pilots will catch the fever that gripped her. And her own sense of awe makes those books so wonderful."

"While Anne was always this great literary figure, I'm not sure she would have had an important book career had her husband not pushed her into it," Berg continues. "As she herself said, he gets a lot of the credit for making a published writer out of her. And while that's going on, she helped him find his own voice. In his early attempts at writing, he was self-consciously literary, and she basically said, 'Write it the way you talk it.'"

Aviation's other great celebrity, the second person to fly solo across the Atlantic, has also received considerable attention from biographers. Doris Rich says that before she began **Amelia Earhart: A Biography** (Smithsonian Institution Press, 1989), she visited the local library, and what she discovered was discouraging. Do you know, the librarian asked her, that there are approximately 30 books and countless magazine articles already published about Earhart? "Well," Rich told her, "I guess I'll have to read them all."

"But no one, except her sister, wrote about her life," says Rich. "Everybody wrote about her death." Rich's book tells Earhart's story from childhood to celebrity-hood, as does another biography published in 1989, Mary Lovell's **The Sound of Wings**.

Rich, who has written biographies of three other women pilots, Harriet Quimby, Mathilde Moisant, and Bessie Coleman, and is now working on a biography of Jackie Cochran, says the work that most inspires her as a biographer is **The Bishop's Boys: A Life of Wilbur and Orville Wright** (Norton, 1989) by National Air and Space Museum curator Tom Crouch. "Tom Crouch can meld the times with the person's life he's writing about in a wondrous way," says Rich. "You know," she confides, "the 'bishop's boys' couldn't have been two more boring men, and he managed to make them interesting."



Early Flight World War I

Part of the fun of reading about this period is that the reader can experience how wild and mysterious the world of aviation once was, both for those who flew and those who built the aircraft.

Contact!: The Story of the Early Birds by Henry S. Villard (Smithsonian Institution Press, 1987). Written in an engaging style, this is probably the best one-stop overview of the pilots and competitions of the period.

A Passion for Wings: Aviation and the Western Imagination by Robert Wohl (Yale University Press, 1994). An excellent scholarly account of early flight, written by an eminent historian.

The Sky Beyond by Sir Gordon Taylor (Peter Davies, 1936). The book starts with the author's sometimes-harrowing World War I experiences, then recounts his later aerial explorations, particularly for commercial air routes.

Sagittarius Rising by Cecil Lewis (MacMillan, 1970). A superb memoir

of World War I and a great coming-of-age book as well.

No Parachute by Arthur Stanley Gould Lee (HarperCollins, 1970). Written many years after the war by a noted Royal Air Force pilot, this is a no-holds-barred look at the war. At times very bitter.

Fighting the Flying Circus by Eddie Rickenbacker (Stokes, 1919; on line at www.richthofen.com/rickenbacker). The famous ace recounts his wartime training.

The Great War in the Air: Military Aviation From 1909 to 1921 by John H. Morrow Jr. (Smithsonian History of Aviation, 1993). The author is perhaps the leading scholar on World War I aviation history, particularly German aviation.

The First Air War, 1914–1918 by Lee Kennett (Free Press, 1991). This book is unique in that it documents the non-combat aspects of World War I aviation, such as the use of balloons for observation and transportation.

Is there any doubt that World War II has been studied and documented more than any other era of aviation history? We are sure that all manner of works about this period will continue to be written long after the last of the combatants is gone.

HISTORIES

Black Thursday by Martin Caidin (Dutton, 1960). Recounts a bombing raid that has been called "the worst single day in the history of the Eighth Air Force." The mission: to destroy ball-bearing factories in the German city of Schweinfurt. The result: 60 U.S. bombers lost, more than 600 crewmen dead, and the factories damaged but still standing.

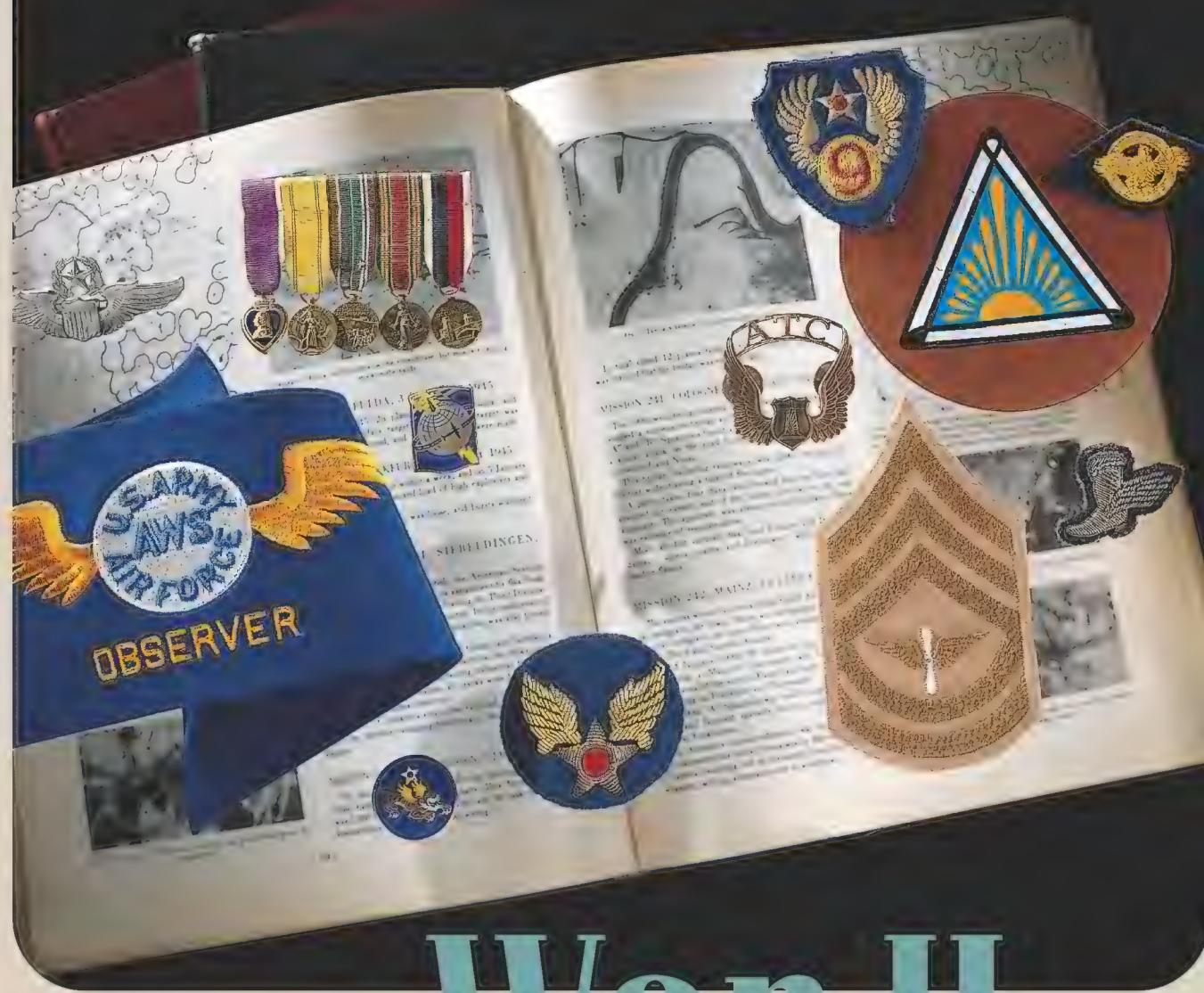
The Narrow Margin: The Battle of Britain and the Rise of Airpower 1930-40 by Derek Wood and Derek Dempster (McGraw-Hill, 1961). An excellent account of the legendary battle.

Wings of Morning by Thomas Childers (Perseus, 2000). The author's uncle was killed when the very last U.S. bomber to be shot down over Europe, a B-24, crashed. Childers found out how, and why.

Flying Tigers by Daniel Ford (Smithsonian Institution Press, 1991). Working with Japanese, British, and American archival records, Ford, an *Air & Space* contributor, pieces together for the first time what may be the most accurate accounting of the combat victories and losses attributed to the American Volunteer Group, or Flying Tigers, during the two years they fought Japanese forces in China and Burma.

Low Level Mission by Leon Wolff (Berkley, 1958). The story behind the enormously costly and ultimately unsuccessful campaign to put the refineries in Ploesti, Romania, out of commission.

Allied Aircraft Piston Engines of World War II by Graham White (Society of Automotive Engineers, 1995). White's encyclopedic treatment covers every manufacturer in the United States and Great Britain, every engine they made, and



World War II

the aircraft in which the engines were used. Advances in engineering and technology that supported the Allied war effort spanned everything from fuels to metallurgy, and it's all covered here.

Flying Fortress: The Illustrated Biography of the B-17s and the Men Who Flew Them by Edward Jablonski (Doubleday, 1965). An overall look at the beast, with copious black-and-white illustrations.

Falling Through Space by Richard Hillary (Reynal & Hitchcock, 1942; Time-Life Books, 1991). Only half of the book is about flying a Spitfire in combat. The rest recounts what it's like to recover from the horror of being nearly incinerated in one.

The First and the Last: The Rise and Fall of the Luftwaffe, 1939-1945 by Adolf Galland (Holt, 1954; Buccaneer Books, 1997). A history of the war from the perspective of a leading Luftwaffe ace and general. (The book includes a few of the author's less proud moments, such as the time his airplane collided with a lamppost.)

REMEMBRANCES

Flights of Passage by Samuel Hynes (Naval Institute Press, 1988). Hynes went into the war a boy and came out a 100-mission Marine ground-attack pilot.

Into the Teeth of the Tiger by Donald S. Lopez (Smithsonian Institution Press, 1997). Don Lopez, now deputy director of the National Air and Space Museum, was just a kid when he was sent to China. By that time, the American Volunteer Group, or Flying Tigers, had been absorbed into the Army Air Forces as the 23rd Fighter Group; it was this unit that Lopez joined. Much more than a military history, this book is a detailed description of daily life in wartime China, from the grinding diet of powdered eggs to the tragedy of a young flier being pinned in a burning airplane.

Serenade to the Big Bird by Bert Stiles (Drummond, 1947; Norton, 1952). Stiles, a B-17 copilot, died over Hanover, Germany, at 23, but first he wrote this moving memoir of war.

God Is My Copilot by Robert L. Scott (Blue Ribbon Books, 1943). Much-loved memoir of the war in China, written by the 23rd Fighter Group's commander.

The Big Show: Some Experiences of a French Fighter Pilot in the R.A.F. 256 by Pierre Clostermann (Chatto and Windus, 1951). The author flew 420 operational sorties as a member of the Royal Air Force's Alsace squadron.

NOVELS

Bomber by Len Deighton (Jonathan Cape, 1970). The best of several air war books by the author of the better known *Funeral in Berlin* and *The Ipcress File*, *Bomber* describes the ghastly world inside Royal Air Force night bombers. Deighton creates a dozen or so plot lines and character threads in a masterpiece of storytelling. Most unusual is his inclusion of the viewpoint of the denizens of a tiny village in Germany that is devastated by bombs dropped off target by the RAF. The author is generous with detail; in a scene depicting the villagers trying to put out the fires ignited by the bombing raid, he even describes the local waterworks. Many people have called this the best novel written about World War II aerial bombardment campaigns. (Warning: Some of it is gruesome.)

Piece of Cake by Derek Robinson (Knopf, 1984). Stuffier Englishfolk hated this marvelous novel because it blends unexpected humor with the horror of flying Hurricanes in the Battle of Britain. A young British flying officer must bring some discipline, order, and a badly needed boost in morale to a dissolute unit of RAF pilots who are burned out from fighting the long, drawn-out battle for Britain's skies.

The Wooden Wolf by John Kelly (Knopf, 1983). This novel follows two night-fighter adversaries, one in the RAF and the other in the Luftwaffe, who clash in a climactic night air battle. Kelly, who flew de Havilland Mosquito night fighters during World War II, writes from experience about the weird early days of blind air combat: the arcane electronics, counter-measures, and counter-counter-measures.

In the literature of commercial aviation, one name dominates: R.E.G. (Ron) Davies, a curator at the National Air and Space Museum who has made a long and prodigious career documenting in detail the histories of Continental, Pan Am, Delta, Lufthansa, Aeroflot, TransBrasil... You get the idea. These days, Davies publishes books on individual airlines via his own company, Paladwr Press.

Of his overall histories, his grandest include **Airlines of Latin America Since 1919** (Smithsonian Institution Press, 1984), **Airlines of the United States Since 1914** (Putnam, 1972), and **A History of the World's Airlines** (Oxford, 1964). As for a few non-Davies classics:

Bonfires to Beacons by Nick A. Komons (Smithsonian, 1978). A scholarly look at the U.S. government's role in developing commercial aviation.

Sky Gods by Robert Gandt (Morrow, 1995). A Pan Am pilot recounts the dramatic story of his airline's fall.

Airways: The History of Commercial Aviation in the United States by Henry Ladd Smith (Knopf, 1944). The title says it all (but note publication date).

Fate Is the Hunter by Ernest Gann (Simon and Schuster, 1961). A pilot's-eye-view of the thrills and dangers of commercial aviation in the 1930s.



Space

Conveying the concept of "space" to an audience with essentially no first-hand experience of it is a mission that requires both vivid writing and patient explanation.

TEST FLIGHT and EXPLORATION

At the Edge of Space: The X-15 Flight Program by Milton O. Thompson (Smithsonian Institution Press, 1992). An insider's account, garnished with Thompson's impish sense of humor, of one of the most successful research aircraft ever flown. Thompson, along with Scott Crossfield, Neil Armstrong, and other legendary test pilots, flew the hypersonic rocket-powered X-15 in the 1960s, and these flights provided essential lessons for planners and pilots of the first manned excursions into space.

On the Frontier: Flight Research at Dryden, 1946-1981 (NASA, 1984) and **Test Pilots: The Frontiersmen of Flight** (Smithsonian, 1988), both by Richard P. Halton. The author, currently the U.S. Air Force Historian, chronicles the intensive flight research done in California's high desert and the personalities of those who flew on space's ragged edge.

Introduction to Space: The Science of Spaceflight, Third Edition by Thomas Damon (Krieger Publishing Company, 2001). Employing scads of drawings, illustrations, and charts, Damon explains the science of space travel in all of its nuances and variables. He describes how space probes navigate interplanetary routes, how satellites stay in orbit, how the space shuttle works, and how rockets manage to lift so many tons of fuel and material into space.

Conquest of Space by Chesley Bonestell (Viking Press, 1949). This book is a must for collectors. Bonestell, an artist and illustrator, published *Conquest of Space* in 1949 with space expert Willy Ley, who wrote the text. It is hard to find—though not impossible, thanks to the Internet—but an essential arti-

fact, predicting with imaginatively detailed illustrations what space travel would be like. Bonestell went on to become a regular contributor to *Life* and *Colliers*, where his illustrations helped fuel public enthusiasm for manned space exploration.

Apollo: The Race to the Moon by Charles Murray and Catherine Cox (Simon & Schuster, 1990). Beautifully researched and written, this is the best account of the engineering effort behind the Apollo missions, and the story of the flight planners who executed Apollo from mission control.

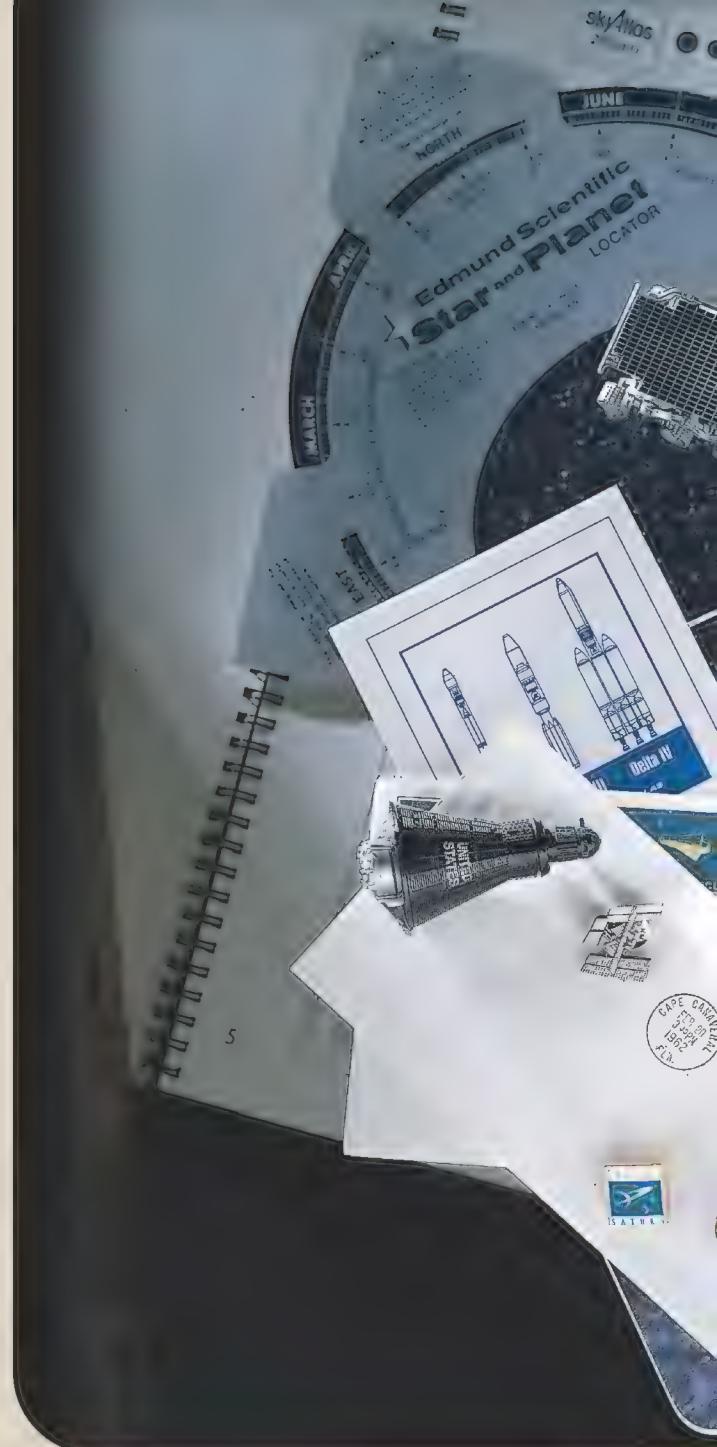
Chariots for Apollo by Courtney Brooks, James Grimwood, and Lloyd Swenson (NASA publication SP-4205, published in 1979; text is available on line at www.hq.nasa.gov/office/pao/History/SP-4205/cover.html). Not to be confused with a book by the same title, about the lunar module.) This thoroughly researched volume covers essential details of the development of the Apollo spacecraft and the planning of the Apollo missions, based on interviews and NASA documents.

To a Rocky Moon: A Geologist's History of Lunar Exploration by Don Wilhelms (University of Arizona Press, 1994). We didn't go to the moon in the name of scientific discovery, but that was one of the adventure's chief rewards. The story of the geologic exploration of the moon is told by one of its key players, in a thorough and highly readable narrative.

Space Shuttle: The History of the National Space Transportation System; The First 100 Missions by Dennis R. Jenkins (Dennis R. Jenkins Publishing, 2001). This book exhaustively documents the shuttle's development and each mission flown until late 2000.

SPACE SCIENCE and ASTRONOMY

Cambridge Star Atlas, Third Edition by Wil Tirion (Cambridge University Press, 2001). This slim, elegant, inexpensive,



and readily available volume is an excellent first foray into high-quality star charts. Tirion is the acknowledged master of celestial cartography, and this book demonstrates why. In addition to the beautiful color charts, it gives detailed information about the stars, galaxies, and nebulas depicted. (More advanced amateurs will likely upgrade to *Sky Atlas 2000* by Tirion and Roger Sinnott.)

Men, Monsters, and the Modern Universe by George Lovi and Wil Tirion (Willmann-Bell, 1989). Lovi was a guru of skylore to a generation of planetarium folk. This book includes a reproduction of Alexander Jamieson's early 19th century sky atlas (plates printed on the left pages), as well as a modern atlas by Tirion, similar to the ones he did for the newer editions of **Norton's Star Atlas** (another recommended title). The latter maps are printed on the right side, so you can compare the old with the new. Jamieson's atlas contained the largest number of constellations of all the old-style "pictorial"



atlases, and each plate is accompanied by a page of constellation lore written by Lovi. A "must have."

Nightwatch: A Practical Guide to Viewing the Universe by Terence Dickerson (Firefly Books, 1998). Amateur astronomers of all levels benefit from Dickerson's thoughtful and comprehensive examination of the pastime. Chapters cover learning the night sky, telescopes and their accessories, planetary studies, and the composition of the universe. Basic star charts in the back have extremely helpful descriptions of key objects printed adjacent to symbols of the object.

Burnham's Celestial Handbook: An Observer's Guide to the Universe Beyond the Solar System by Robert Burnham Jr. (Dover Books, 1983). Although the science in this three-volume work is now quite out of date, this is far and away the most interesting and readable treatment of the sky and all of its wonders. It summarizes the legends behind almost every constellation and

describes in great detail hundreds of clusters, nebulae, and other objects. Burnham was an eccentric who worked for years at the Lowell Observatory in Flagstaff, Arizona. When he lost his position there he drifted through various states of homelessness, passing away in a San Diego park in 1996. Burnham never really profited from the books, but tens of thousands of amateur astronomers know the 1,600-plus pages intimately.

Star Names, Their Lore and Meaning by Richard H. Allen (Dover, 1963). The quintessential reference on the origins of star and constellation names.

The New Solar System, Fourth Edition by J. Kelly Beatty, Andrew Chaikin, et al. (Cambridge University Press, 1998). This is about as technical as one can get without tripping the reader up with jargon. It features chapters on each of the major bodies of the solar system and extensive detail on the smaller ones as well. Some 30 authorities in planetary studies contributed.

Secrets of the Astronauts

The U.S. space program has inspired a copious collection of tales, replete with heroic adventure, technological sorcery, and bureaucratic derring-do. By far the best is the deservedly famous **The Right Stuff** by Tom Wolfe (Bantam Books, 1983). A brilliant piece of journalism and an all-around great read, *The Right Stuff* explores in great detail the astronaut training program, the psychology of the test pilots who became the early astronauts, and the lives of the Mercury crew—warts and all.

The Apollo program is well documented in **A Man on the Moon** by *Air & Space* contributor Andrew Chaikin (Penguin USA, 1998). This excellent narrative, which describes the personalities behind the program as well as the technology, inspired the acclaimed HBO miniseries "From Earth to the Moon."

The astronauts have done their share of writing as well. The best of this category, hands down, is **Carrying the Fire** by Michael Collins (Adventure Library, 1998). As a writer, Collins is the Lindbergh of the astronaut corps. Buzz Aldrin and Malcolm McConnell wrote **Men From Earth** (Bantam, 1989) to offer not only an account of Aldrin's spaceflight experiences but also a picture of the U.S. and Soviet efforts during the moon race.

The shuttle program has spun off its own set of scribes. On his mission, Jeff Hoffman did something every astronaut should: He brought a tape recorder on the shuttle and noted his thoughts and experiences. The results, **An Astronaut's Diary** (Caliban, 1986), have a striking immediacy. **Entering Space** by Joe Allen (Stewart, Tabori & Chang, 1987) is a nice coffee table collection of images and text, probably the best book by a shuttle astronaut.

Finally, for a juicy exposé of what went wrong during the Mir-shuttle program of 1994 to 1998, check out Bryan Burroughs' **Dragonfly** (HarperCollins, 2000), based in part on interviews with unhappy crew members.

Flying for the fun of it still requires serious attention to detail, of course.

The following books document all different aspects of an experience that, when done well, could never be called a "hobby."

The Student Pilot's Flight Manual (Eighth Edition) by William K. Kershner (Iowa State University Press/Ames, 1998). Even if you have no plans to pursue a pilot's license, you'll want to keep this book on hand for explanations of aerodynamics, cockpit instrumentation, navigation techniques, airspace classifications, sectional charts, and the occasional Kershner cartoon of a pilot who has gotten himself into a dicey situation; one is captioned: "The roughness of the engine is directly proportional to the square of the roughness of the terrain and the cube of the pilot's imagination."

Fly Low, Fly Fast: Inside the Reno Air Races by Robert Gandt (Viking, 1999). This book provides a riveting account of the 1997-98 Reno Unlimited-class air races and intimate portraits of the colorful characters who race the souped-up World War II fighters at death-wish speeds and altitudes in the high desert. Gandt's writing style is reminiscent of Tom Wolfe's *The Right Stuff* ("Whooooom! The T-33 flashed overhead. Hinton could see that Smoot had gotten stopped. He'd avoided the great fighter-eating abyss out there in the desert").

Skyward: Why Flyers Fly by Russell Munson (Howell Press, 1989). Scattered among Munson's stunning photos are interviews with a cross-section of pilots: a Concorde captain, a P-51 owner, a corporation president who started flying at 49, and now, at 71, flies her own Cessna Citation. A book editor admits that when weather prevents him from flying his Cessna 172, "I'll go out sometimes and just sit in the damn thing." One of Munson's own stories recounts the challenge of logging 13.5 hours in a DC-3 to get a type rating. On DC-3 brakes: "It's like the first time you stomped on the power brakes of a '55 Chrysler and launched your Mom into the glove compartment." One vertigo-inducing photo captures Munson's blue-

jeaned legs suspended 1,000 feet over North Carolina's Outer Banks in an Eipper-Formance ultralight.

Flight of Passage: A Memoir by Rinker Buck (Hyperion, 1998). In 1966, the author, then 15, and his brother, 17, flew their immaculately restored Piper Cub from New Jersey to California, on a mission to emerge from the towering shadow of their father, a former barnstormer, and simultaneously earn his respect and their independence. This coming-of-age classic, told from the cockpit of an airplane with nothing more than a compass to guide it from coast to coast, reached a broad audience but was especially treasured by the aviation community.

The Airman's World by Gill Robb Wilson (Random House, 1953). The mod-

est exterior of this book conceals a treasury of penetrating aviation poetry and prose. Each of the 33 writings is paired with a full-page black-and-white image by some of aviation's greatest photographers. Many of these pieces first appeared in *Flying* magazine during the 1950s. Wilson was a pilot during World War I, an ordained pastor in the 1920s, a New Jersey state aviation official in the '30s, a newspaper correspondent in the '40s, and *Flying* magazine's publisher and editor in the '50s and '60s. He was a co-founder of the Aircraft Owners and Pilots Association, an architect of the Civil Air Patrol, and a participant in the creation of World War II's Civilian Pilot Training Program. It is his gift of communicating that earns this unpretentious volume a place on your bookshelf.

General/Sport/Recreational Aviation



Can the experience of flight be fully rendered with language alone? These books supplement the written literature with visual images, some so powerful they have an almost physical effect on the reader/viewer.

Steichen at War by Christopher Phillips (Harry N. Abrams Inc., 1981). A master photographer's black-and-white photographs documenting World War II, including the airplanes and air crew.

Women and Flight: Portraits of Contemporary Women Pilots by Carolyn Russo (Smithsonian Institution Press–Bulfinch Press, 1997). A National Air and Space Museum staffer's strong black-and-white portraiture of women fliers, from student pilots to pioneers.

Looping the Loop: Posters of Flight by Henry Serano Villard and Willis M. Allen Jr. (Kales Press, 2000). Beautiful aviation posters that span the years of early flight, the Golden Age, and World War II.

Full Moon by Michael Light (Knopf, 1999). Stunning black-and-white photographs made by the astronauts during the lunar missions.

The Art of William S. Phillips: The Glory of Flight, introduction by Stephen Coonts (The Greenwich Workshop, Inc., 1994). Not a nuts-and-bolts treatment of aircraft. Phillips is more like a landscape painter; he uses wonderful muted colors to make you feel like you're in the air.

Aviation, The Early Years: The Hulton Getty Picture Collection by Peter Almond (Konemann UK Ltd., 1997). Rare photographs documenting the early days of flight. Some of the whimsical-looking designs will make readers smile. (To think that these flew at all!)

Ghosts of the Skies: Aviation in the Second World War by Philip Makanna (Chronicle Books, 1995). The grace of these old warbirds and the lovely landscapes in which they are shown flying make an unbeatable combination. Also includes archival black-and-white photographs.

The Cutting Edge by C.J. Heatley III (Thomasson, Grant & Howell, 1986). The



Photography & Art books

best photographic portrayal of carrier aviation. Heatley puts you right on the carrier deck, where your very bones vibrate as an F-14 is hurled into the sky.

Wings by Mark Meyer (Thomasson-Grant, 1984). Does for Air Force aviation what *The Cutting Edge* does for naval aviation.

Air to Air by Paul Bowen (North Shore Press; two-volume set, 1998 and 2000). Bowen is known for photos of vortices trailing off bizjets and dramatic in-your-face shots of jets at takeoff. He shoots at dawn and dusk to get the soft colors.

Front Row Center: Inside the Great American Airshow by Erik Hildebrandt (Cleared Hot Media, 2000). An *Air & Space* contributor's work transports you to the world of airshows. Includes many tight air-to-air shots.

NASA and the Exploration of Space by Roger Launius and Bertram Ulrich Stewart (Stewart, Tabori and Chang, 1998). The work of more than 85 artists portraying the U.S. space program.

Our Panel of Experts

- Scott Berg, biographer
- William Burrows, aerospace historian and author
- Andrew Chaikin, author, *A Man on the Moon*
- Geoff Chester, Public Affairs Officer, U.S. Naval Observatory
- Richard P. Hallion, U.S. Air Force Historian
- Dan Hagedorn and Brian Nicklas, National Air and Space Museum Archives
- Peter Jakab, curator, National Air and Space Museum
- Phil Jordan, founding designer, *Air & Space/Smithsonian*
- J. Campbell Martin, external affairs, NASA-Dryden Flight Research Center, California
- Leonard E. Opydcke, publisher, *WWI Aero and Skyways*
- Doris Rich, biographer
- Chad Slattery, aviation photographer
- F. Robert van der Linden, curator, National Air and Space Museum
- Stephan Wilkinson, writer

Resto

Delightfully de Havilland | D.H.89 Dragon

He traded a DC-3 for it. That's how much John Schell wanted a Dragon Rapide, a lovely little 1930s British airliner manufactured by de Havilland. In 1992, Schell swapped airplanes with his friend Mike Kimbrel, a Delta Air Lines captain. To pick up his Dragon, Schell drove from his home in Puyallup, Washington, to Kimbrel's place in Oakville. There, Schell disassembled the wood-and-fabric biplane, loaded its wings and tail feathers on a flatbed trailer, and returned to Puyallup, leaving behind the fuselage, which was too large to move by road.



NASM NEG. 94-13267

Their cockpits designed for superb visibility (below), D.H.89s served the Royal Air Force as trainers. Before it was restored, the Dragon was named after the wife of previous owner Mike Kimbrel (above, right).



CHAD SLATTERY

At his shop, Schell and sons, Kevin and Toby, and grandson Jake worked steadily for four months to restore the Dragon's tail and wings, replacing wood ribs where needed. They then brought those parts back to Kimbrel's place, where they reassembled the airplane and flew it home to Puyallup. But Schell wasn't satisfied with just an airworthy craft; he wanted to restore the airliner to its vintage luster. For the next 12 months, Schell and his team went to work on the fuselage.

The prototype of the D.H.89 Dragon Rapide first flew on April 17, 1934, and



COURTESY JOHN SCHELL

a total of 727 aircraft were manufactured between 1934 and 1946. During its heyday, the D.H.89 served as a transport for oil companies, as a commercial airliner in Canada, and as a courier between England and France during World War II. Schell's Dragon had served as a survey platform in India, where it was purchased by airplane dealer Buzz Gothard of Curtis, Washington. Kimbrel bought it from Gothard in 1976.

Compared to today's airliners, the Dragon Rapide was tiny, carrying only eight passengers and a modicum of luggage. The only crew was the pilot ("It's a captain's airplane," says Schell. "You don't have to share the flying with anybody.") Passengers were transported in an unpressurized cabin at altitudes of 3,000 to 6,000 feet. No meals were served, and many Dragon Rapides, which flew for three hours without stopping, had no bathrooms.

Schell retired from Northwest Airlines in 1992 as a Boeing 747 captain; during his 28-year career he also flew the DC-7 and DC-10 and the Boeing 707 and 727. Though he loved flying jetliners, he raves about the propeller-driven Dragon. "This is a real lady to fly," says Schell. "It's a beautiful airplane. Everybody that's ever had a ride in it, they just—like a lot of my friends that fly for the airlines—they get in and go for a ride and they come back and they think, *Oh my gosh, this should be an airliner. This is really a real airplane.*"

Schell's first job was to refabricate the entire fuselage. Though the original fabric was either cotton or Irish linen, Schell went with a synthetic, lapping and gluing it over the 34.5-foot-long fuselage. "On these polyfiber finishes, you don't do like they used to do with cotton," says Schell. "It used to take four coats of dope to bring it up taut. Okay, these [polyfibers], there's three sessions with a hot iron. And it just slowly draws it up, just like a drum." To protect the cloth from sunlight, Schell

Dragon Rapide



CHAD SLATTERY (3)

painted on a layer of silver-colored dope.

When Schell took possession of the D.H.89, it still had the original seats. "It had horsehair seats that were extremely heavy, and they didn't smell very good," he says. He painted the seat frames and fashioned new seat cushions with synthetic foam. The rest of the Dragon's cabin had been stripped, so Schell installed a blue and gray interior.

As for the airliner's two de Havilland Gipsy Queen 3 engines, they ran well and only required cleaning, new spark plugs, oil changes, and fireproofing of the fuel lines. When the restoration was complete, Schell had spent only \$13,000 for materials, but he estimates that the labor was worth at least \$200,000.

He has taken the Dragon to airshows all over the West coast and to the annual fly-in at Oshkosh, Wisconsin. "You know, you take it to an airshow, and it



(Clockwise from above): The Dragon is as lovely to fly as its appearance suggests. John Schell, grandson Jake, and sons Kevin and Toby (left to right) replaced the side windows and installed safety glass in the cockpit.

doesn't matter what's there—it's even been beside a B-17 and a B-24—and the crowd just seems to go to it," he says. "And of course, everybody wants to take a ride in it." It is the only flying Dragon Rapide in the United States.

Still, Schell feels it is time to move

on, and he's looking for another airplane to restore. First, though, he'd like to sell the D.H.89 to a buyer who would appreciate it. "I've had this one for over ten years," he says, "and I think it's time for somebody else to have some fun."

—Diane Tedeschi



I Survived the Rotary Rocket



***"Nothing in
Navy test pilot
school prepared
me for this."***

BY MARTI SARIGUL-KLIJN

In 1999, I had the opportunity to fly one of the most unusual aircraft ever built and certainly one of the most difficult to fly. The Atmospheric Test Vehicle looked like a huge traffic cone with a tiny rotor on its top. I was its pilot, and one of my best friends, Brian Binnie, served as its copilot. Brian, like me, was a Navy test pilot school graduate and a former U.S. Navy commander. Together, we had 24 years of flight test experience, and yet nothing had prepared us for the difficulty in testing the ATV.

At the time, I worked for the Rotary Rocket Company, founded by two of the nicest guys that I'd ever met: Gary Hudson and Bevin McKinney. I had joined Rotary as one of its first employees after finishing 20 years in the U.S. Navy, most of it in flight test.

Based in Mojave and Redwood Shores, California, the company had been formed in 1997 to cash in on what was supposed to be a huge increase in the small satellite-launch market. Gary and Bevin's plan was to develop and bring to market the first launch vehicle that was fully reusable; even more ambitious, it was to be the first single-stage-to-orbit launcher. The vehicle, which they called Roton, would take off vertically, powered by a spinning engine that contained 72 small rocket engines arranged around its base in a circle. After delivering a payload to low Earth orbit, the craft would turn around and unfold its helicopter blades. It would then reenter Earth's atmosphere, base first.

The Roton concept generated intense interest and enthusiasm; over 30 private investors provided us with millions of dollars in funding. But even with all the support and interest, we knew that it would take hundreds of millions of dollars to build the Roton. We also realized that this kind of investment would not be available to a small startup company unless we completed some spectacular milestones early in the program.

Our early studies showed us that small rocket engines would be needed in the tips of the helicopter blades to keep the rotor spinning during the final flare to touchdown. We realized that with an extra-large supply of tip-rocket fuel, we could build a full-scale

vehicle that would be able to climb to a high altitude and then fly the Roton's final approach and landing. This was the genesis of the ATV, which would serve as a landing demonstrator for the Roton.

We picked Burt Rutan's Scaled Composites Company in Mojave to build the ATV's composite airframe, and about a dozen small contractors to build or supply components such as the landing gear, control system components, and software. Some of the parts, like the tip rockets, we designed and built ourselves because we could not find contractors to build them.

Construction started in August 1998. The project took on the air of the British television show "Junkyard Wars." When Brian and I found out that helicopter crew seats cost about \$100,000 new, we started searching aircraft junkyards. We found two from a crashed helicopter and bought them for \$500 each. A new rotor head would cost over \$1 million, but our crew chief found one from a helicopter that had sheared off its tail in a crash; it was undamaged and cost only \$50,000.

We needed 4,300 pounds of hydrogen peroxide to power the ATV's tip rockets. Unlike the three percent solution sold in drugstores, the peroxide that the ATV used was a much more dangerous 85 percent. This fuel cost over five dollars a pound, and the ATV consumed about 1,000 pounds a minute, so flights would be limited to two to three minutes.

The vehicle's cockpit, located on the side, was very similar to a standard helicopter cockpit. In my right hand, I had a cyclic stick that looked and operated like one in a helicopter, and I used it to control pitch and roll. My left hand held the collective. By raising it, I increased the angle of the rotor blades, which in turn caused the ATV to climb. Lowering it caused the ATV to descend. At the end of the collective lever was a throttle similar to those found on motorcycles. I used it to control the thrust of the tip rockets.

Unlike a conventional helicopter, the ATV did not have a tail rotor. My feet pushed two pedals that steered three additional rockets (called yaw thrusters) located at the rear of the vehicle, behind the crew cabin. Pushing

the left pedal turned the ATV left; pushing the right pedal turned it right.

To test the rotor, we built a stand in the bottom of a quarry some 35 feet below ground level. The sides of the quarry would stop any parts that might fly off during testing (none did). We ran the rotor eight times on the test stand while we figured out how to start and stop the thing. What we learned was that it was very difficult to control rotor speed, because the tip rockets took more than one second to react to any change in the throttle. Also, the rotor was unstable at operating speed. An increase in rotor speed, or rpm (revolutions per minute), would cause the tip rockets to produce more thrust, and that would make the rpm go even higher. As rpm wound down, the reverse behavior occurred. I had to constantly fiddle with the throttle to hold rotor speed constant. It turned out to be very easy to overspeed the rotor, which could cause the rotor blades to fly off.

Our simulator was built right into the ATV cockpit and ran on a PC. It used the existing cockpit controls, and the pilot flew by looking at a temporary video monitor placed in front of him on a small plywood table. I believe this is the first time a test aircraft had its own built-in simulator.

Test pilots rate aircraft using what is called the Cooper-Harper scale, in which a "1" means an aircraft that's nice to fly and a "10" means an aircraft so difficult to fly that control will be lost during some portion of the flight. Eventually we would have over 75 civilian and military test pilots fly the ATV simulator, most with at least 1,000 hours of flight time, and even after several hours of practice on the simulator, they all rated the ATV a "10." I had over 5,000 hours of flight time in 70 models of aircraft, and even after over 10 hours of practice, I could just barely complete a simulated takeoff and landing without crashing. While an orbital version would be flown by computer control, our test vehicle had only one computer: me. We could not afford a computer-controlled stability augmentation system.

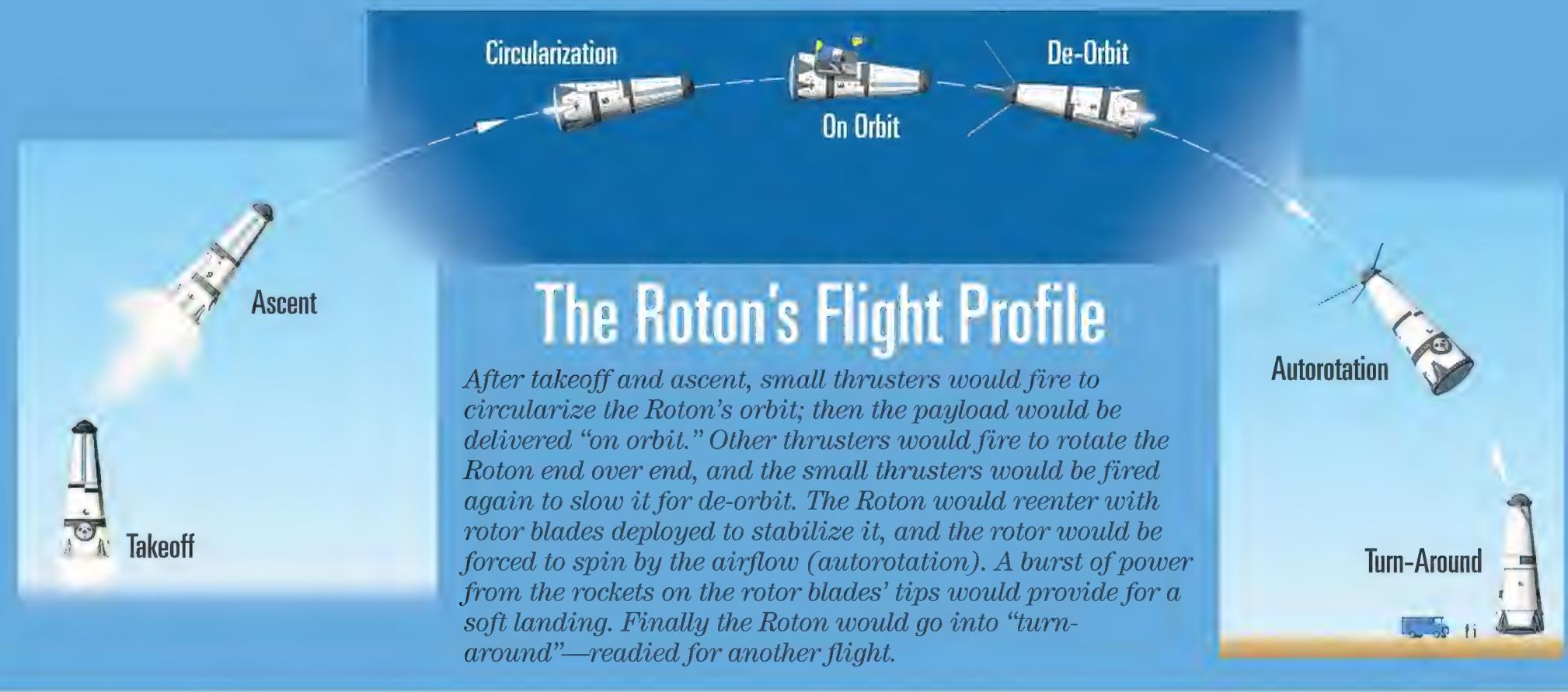
The ATV offered other challenges. We started calling the cockpit "the bat cave" because the view out of it was so limited. We could not even see the rotor blades. To simulate the view, I fashioned myself a hood, sort of like a nun's, out of cardboard and masking tape. I then practiced flying helicopters with the hood (I had another pilot on board to



The Atmospheric Test Vehicle's rotor blades had small hydrogen-peroxide-powered rockets on their tips, each providing up to 350 pounds of thrust to power the rotor (above and top).

keep me out of trouble). And to simulate the height of the ATV—it was as tall as a six-story building—I practiced flying helicopters with 25-pound weights attached to 60-foot lines extending beneath them, taking care to keep the weights from touching the ground.

After we had tested the rotor in three ground tests, we



The Roton's Flight Profile

After takeoff and ascent, small thrusters would fire to circularize the Roton's orbit; then the payload would be delivered "on orbit." Other thrusters would fire to rotate the Roton end over end, and the small thrusters would be fired again to slow it for de-orbit. The Roton would reenter with rotor blades deployed to stabilize it, and the rotor would be forced to spin by the airflow (autorotation). A burst of power from the rockets on the rotor blades' tips would provide for a soft landing. Finally the Roton would go into "turn-around"—readied for another flight.



The crew climbed up to the cockpit using a ladder that had been built onto the ATV. Once they had entered "the bat cave," the pilot and copilot were unable to see the vehicle's rotors.

had only 10 days to get the ATV ready for its first flight. Our only hope was that a successful flight might bring in more investment money to keep the flight test program going.

I decided we would just hover the ATV at five to 10 feet for a couple minutes, then land. The team worked non-stop to get the ATV ready. By that point, the company had had to lay off many employees, but they still worked the last 48 hours straight without any rest.

We made the first flight on July 23, 1999, less than one year from the date that we started building the first ATV parts. In the early morning we towed the ATV out to the end of Runway 30 at the Mojave Airport. The weather was already hot but the winds were calm.

We had tried to keep the flight date quiet, but several hundred spectators showed up to watch, including a BBC film crew and three representatives from the Federal Aviation

Administration. If we messed up now, the whole world would know.

After about 10 minutes of operation during our pre-start checks, the ATV's onboard computer suddenly locked up. We used this computer not only to record flight test data but also to display rotor start information on a monitor. The computer had never locked up in our simulator and ground tests. After considerable discussion, we rebooted the computer and continued with our 36-page checklist. Then, just prior to starting the rotor, the computer locked up again. We decided to reboot it one more time and immediately start the rotor before the computer had a chance to lock up again.

This time, just as we started the rotor, the computer failed yet again, only three minutes after being rebooted. With the rotors now turning, we had two choices. One was to shut down. Unfortunately, after each run, the tip rockets had to be removed and cleaned; otherwise they might unexpectedly stop due to catalyst debris left during shutdown. Cleaning would take most of the day, and today was everyone's last day of work, so shutting down now would mean we would not be able to fly at all. Our other choice was to accept that no data would be recorded and that I would have to use the backup gauges to fly.

We were burning fuel at 1,000 pounds a minute. A decision had to be made fast. I raised the collective while Brian adjusted the throttle to maintain 220 rpm on the rotor. Suddenly I heard the low-rpm warning tone. The rpm was down to 180. I told Brian to add throttle. He told me it was at full already. We did not have enough power to fly. That was an unpleasant surprise; our simulator had promised that full throttle would give us a healthy 1,000-foot-per-minute climb.

At this point I should have stopped the flight; the most basic rule of flight test is to plan the flight and then fly the plan. Instead I decided to lower the collective and let the rotor spin up to its maximum safe speed of 260 rpm. I then quickly raised the collective and used the energy stored in the rotor to jump the ATV into the air. Although the procedure might get us into the air, I knew there was a good chance that as the rotor slowed and the ATV came back down, the

vehicle would have a hard landing or maybe even fall over.

Adding to my troubles was the collective pusher that we had installed as a safety device after the first rotor ground test. In case of a rotor overspeed, the pusher mechanically pushed the collective up to lower the rpm. To jump the ATV, I was operating at a rpm above the set point for the collective pusher. I was actually pushing down on the collective and fighting against the pusher. Needless to say, pushing down collective to climb is not a natural act and was something that I had never practiced before.

The jump worked, but not for long. At about five feet, the rotor rpm began to slow down, and despite full throttle the ATV slowly descended to the pavement. Again I lowered the collective to increase the rpm, and off again we went into the air. Again we soon found ourselves back on the ground.

The ATV used fuel at about the same rate as a jet engine in full afterburner, so for the third jump it was about 1,300 pounds lighter. At that lighter weight, we figured that a jump would get us higher in the air. For once we were right—we climbed to 10 feet. However, the jump was a bit off-center, and we started wobbling like a slow pendulum, since the ATV, like most helicopters, was inherently unstable in hover, and the ATV's great height exaggerated that. Whenever the ATV wobbled side to side, it also wanted to turn left or right. We discovered later that another problem was that the yaw thrusters were producing only about 60 percent of the thrust we had predicted and rehearsed to in the simulation. Of course the rotor rpm was decaying as before and we started down. A hard sideways landing could cause the ATV to fall over. Fortunately, the ATV was swinging back through the vertical as the right gear made contact with the ground in a slight left drift. Our flight time had been less than a minute.

After shutting down, we pretty much figured that we had failed. We hadn't hovered for two or three minutes, as we had planned, and we had not recorded any data. However, everybody watching thought the flight was a great success. Folks were smiling, shaking our hands, and telling us what a great job we had done. And our finance people were happy with the results; they rushed together a videotape of the flight to send to our investors. Two weeks later we had enough money to continue.

Our first order of business was to figure out why the ATV could not climb. With the computer locked up we hadn't recorded any data. After weeks of detective work, we discovered that the tiny orifices that metered pro-



A "glamour shot" endows the enormous traffic cone with a look of seriousness that it lacked in flight. Below: The rotor being tested in a quarry.





The rotor head, salvaged from a crashed helicopter, cost the company \$50,000; a new one would have cost over \$1 million. Below: In forward flight, the ATV tilted so much that without seat belts, the crew would have slipped off their seats.



pellant into the tip rockets were a few thousandths of an inch too narrow. We fixed that problem. The computer lock-up turned out to have been caused by a software change made the night before the flight. We also decided to install an auto-throttle to make the ATV rotor speed easier to control. The auto-throttle would electronically monitor the rpm gauge and run a small motor that would increase or decrease the throttle in such a way as to hold the rotor at a constant rpm.

The second flight was flown almost two months later, on September 16, 1999. It was everything that the first flight wasn't: This time we flew the plan. All our fixes worked, and we were able to maintain a steady hover for over two and a half minutes at 10 to 15 feet. But while my flying was better, I was still having trouble holding heading and the ATV still wobbled slightly from side to side. The auto-throttle system was more sluggish than expected. We decided to add a mechanical device that would increase or decrease the throttle when I raised or lowered the collective.

We made our third and final flight on October 12, 1999. Immediately after liftoff I pushed the control stick forward to fly down the length of Runway 30. As we accelerated the ATV tilted almost 20 degrees. Soon we found ourselves staring at the ground. Without seat belts we would have slid off the seats. I climbed to about 75 feet and held at 50 knots. We accelerated so fast that we left our chase cars 2,000 feet behind us. We also started shaking so violently I could not read the instrument gauges. After the flight, we found the catalyst tank had broken free due to the severe vibrations and was hanging by its hoses. If the hoses had broken, we would have lost tip rocket thrust and crashed. We figured out that the vehicle was flying through the wake of its own rotor tip rockets. The drumming on the airframe was exaggerated because the cockpit was at the wide end of the megaphone-shaped vehicle. In hover, the tip rockets' exhaust had missed the fuselage, so we had not experienced this problem before.

Halfway down the runway, I brought the ATV back to a hover. I decided to use the rest of the propellant to hover over one spot, giving people on the ground time to take photos. Brian and I then started to talk about the tremendous vibrations we had just experienced. That was when I noticed that we were in an absolutely steady hover about 30 feet above the ground. No wobbling, no turning, no climbs or descents.

After little more than five minutes of actual flight time acquired over three months, I had mastered the beast and I wasn't even concentrating. My hands and feet moved without conscious effort, correcting for every subtle wobble and turn. I felt both elated and amazed.

But in the weeks that followed this success, it became clear that the Roton would attract no customers. Several satellite telephone companies had declared bankruptcy; the market was going bust. A month later Gary Hudson pulled the plug on the ATV program.

Soon afterward the Rotary Rocket Company abandoned the Roton concept as being too technically ambitious. In early 2001, the company went out of business. The ATV now stands abandoned in its Mojave hangar. 

AT 8:53 A.M. ON SATURDAY, OCTOBER 14, 1961. *Pacific Air Lines flight 715 from Sacramento rolled to its gate at Los Angeles International Airport and shut down its engines for 12 hours. At ticketing posts, a corps of temporary guides straightened their "World Way Blue" uniforms and accepted 50 cents for 20-minute tours of the new passenger terminal and the ramp. Inside the Pan Am 707 Jet Clipper Liberty Bell, stewardesses poured fresh Hawaiian fruit juice.*

At every gate across the airport, airliners were receiving visitors but not passengers. United showed off its DC-8 and Boeing 720 jets, Convair 340, and Douglas DC-7A cargoliner. Bonanza opened its Fairchild F-27; Pacific Air Lines a Martin 4-0-4, and National Airlines a Lockheed Constellation. On the LAX ramp sat Western Airline's tiny 1926 Douglas M-2 biplane.

LAX was only one of many airports to shut down. Nationwide, 50 civilian airports held open houses. But most passenger terminals just turned off the lights. Except for aircraft in Hawaii, the entire U.S. and Canadian commercial fleets and all civilian aircraft were grounded.

On that day, and on two others in the early 1960s, the airliners had to make way for waves of B-52 and B-47 bombers that were to cross from Canada into the United States and enter the continent from the coasts in a simulated Soviet nuclear attack. The three simulations, known as Sky Shield, were training exercises for the personnel, communications, and radar detection systems of North America. The plan was to make sure that the bombers were detected by radar and other early-warning systems, that interceptor

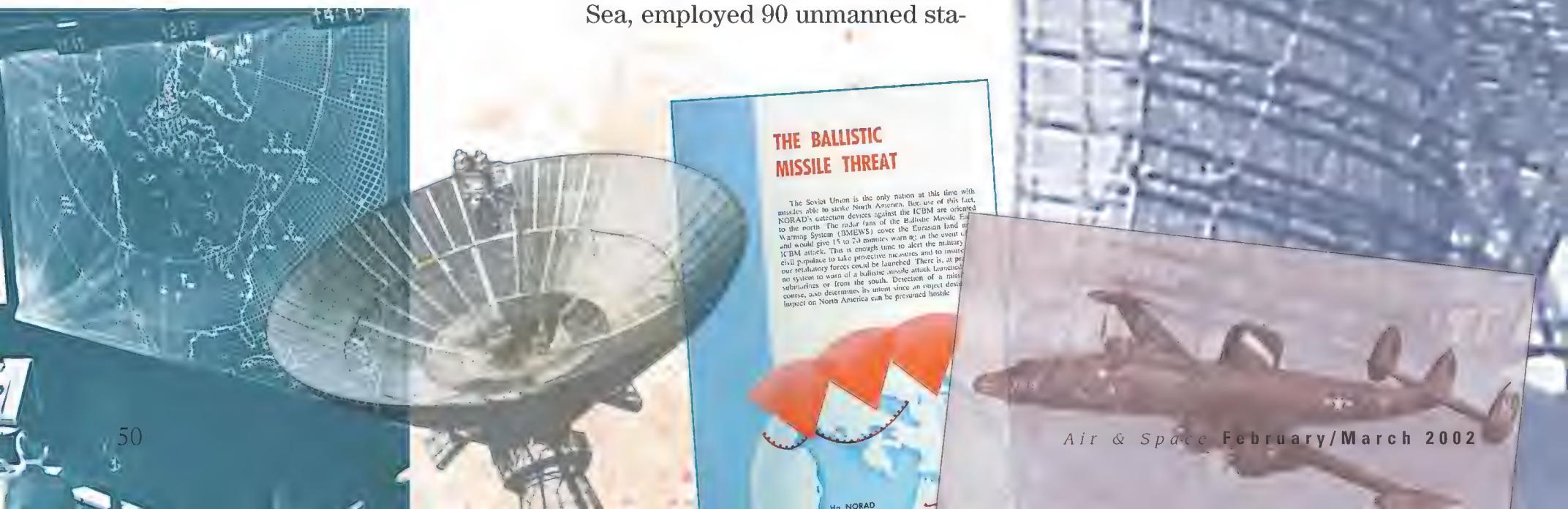
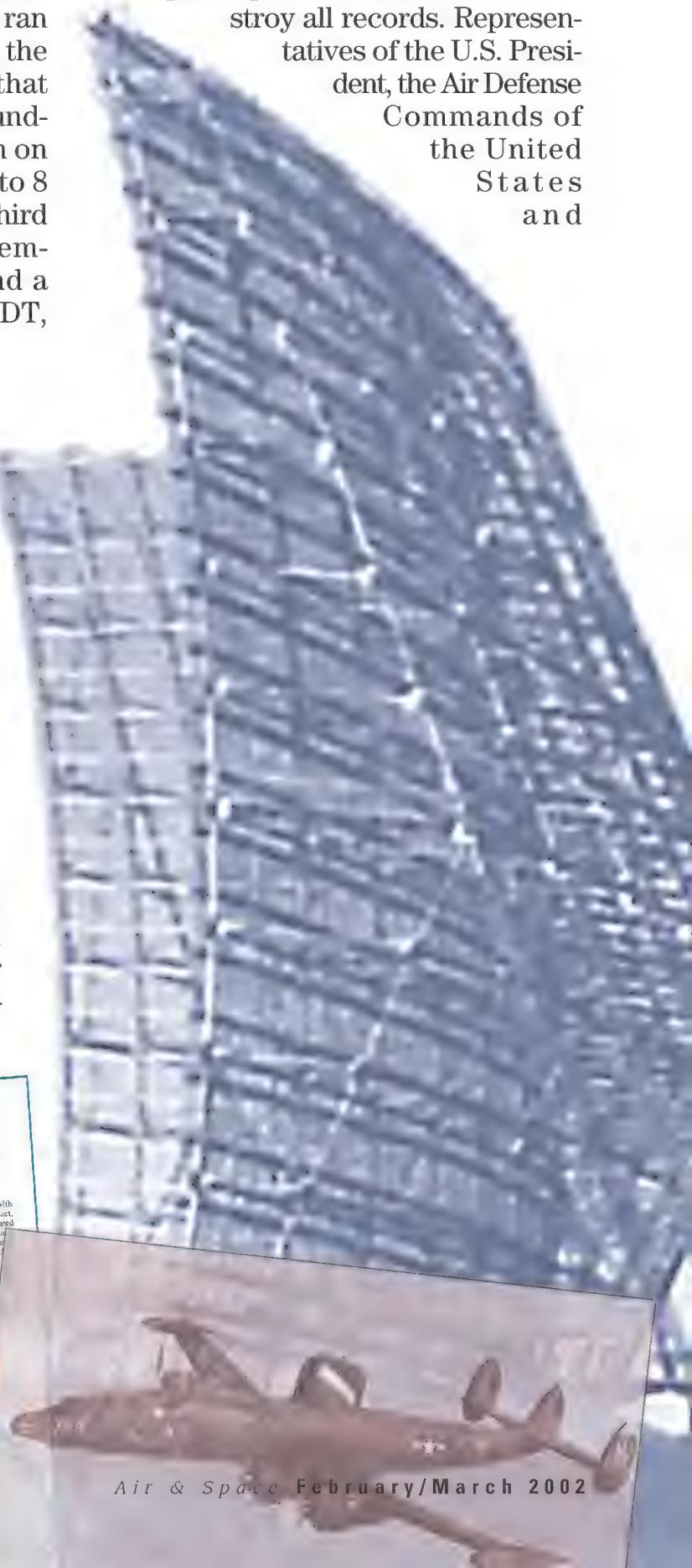
and missile squadrons would be alerted and scrambled, and that the United States would remain able to strike back.

Operation Sky Shield II, which ran for 12 hours in October 1961, was the second time—and the longest—that U.S. civil air traffic had been grounded. The first was Sky Shield I, run on September 10, 1960, from 2 a.m. to 8 a.m. Eastern Daylight Time. The third and final time—until last September—was Sky Shield III: five and a half hours beginning at 3 p.m. EDT, September 2, 1962.

In 1951, 30 radars—the Pine-tree Line—were constructed along the U.S.-Canada border. By 1954 Pinetree provided early warning of threats and control of friendly aircraft. In 1953, the first station of the more capable Distant Early Warning Line opened at Barter Island, Alaska. By 1957, nearly 60 DEW Line radars were installed 100 to 500 miles apart, within two degrees of the 69th parallel from Cape Lisburne, Alaska, to Cape Dyer, Baffin Island. The new Mid-Canada Line, which ran along the 55th parallel from British Columbia to the Labrador Sea, employed 90 unmanned sta-

tions consisting of an electronic "trip wire," an application of the Doppler effect, to detect aircraft.

Continental air defense seemed technically capable, but, untested by war, its true reliability was unclear. General Earle Partridge, commander-in-chief of North American Air Defense Command, hatched a plan for the first live test of the entire continental air defense force. Operation Sky Hawk was set for September 1959 but canceled days before, under the new NORAD commander, General Laurence S. Kuter. Would-be participants were advised to destroy all records. Representatives of the U.S. President, the Air Defense Commands of the United States and



**This is
only a
test**

BY ROGER A. MOLA PHOTO ILLUSTRATIONS
BY DAVID POVILAITIS ON A SINGLE DAY IN
AUTUMN, FOR THREE CONSECUTIVE YEARS,
THE DEPARTMENT OF DEFENSE GROUNDED THE
AIRLINES, AND THE U.S. AIR FORCE RULED THE SKIES.

Canada, and the Canadian Chiefs of Staff Committee revisited the plan at Camp David, Maryland, on November 7, 1959, agreeing to the first (new and improved) joint exercise.

In October, the Ballistic Missile Early Warning System, which consisted of both detection and tracking radars, opened at Thule, Greenland. Detection radar was a fixed fan parabola, 165 feet high and 400 feet long—a football field on its side sending an invisible "V" 2,000 miles north toward the Soviet Union. The screen could withstand earthquakes and winds of 180 mph. Within the installation's radomes were 55-ton tracking radars, which followed objects horizon to horizon.

If the ground-based radars, airborne radars, and sea-anchored radar platforms called Texas Towers worked as promised, NORAD expected advance

warning of 12 to 20 minutes should an "air-breathing" attack occur along a 5,000-mile line looking north, from the Aleutian Islands to eastern Greenland. Ears and eyes reached out 3,000 miles toward the Red Menace, with the ability to detect a reflecting surface of one square foot—a basketball, or in practical terms, the nose of a B-47-type tar-

Left to right: ICONORAMA, Canada's Prince Albert tracker radar, WV-2 Warning Star, Ballistic Missile Early Warning System, NORAD brochure, General Kuter (left) sits with British officers, Century Series interceptors.



get. The ICONORAMA at Colorado Springs, the movie-screen-size display tracking all aerial activity in North America, displayed the DEW and Mid-Canada Line blips—up to 95 percent of targets, head-on, flying between 200 and 65,000 feet, within radar line of sight out to 150 miles. Low-altitude detection, mainly by the DEW Line, was projected to be valid from the surface to 10,000 feet.

Data from the DEW Line was fed to the four-story blocks on Strategic Air Command bases containing the 250-ton IBM computer called Whirlwind II, each of which had 49,000 vacuum tubes housed in a bunker that was reinforced to resist all but a direct nuclear hit. Controllers had previously used slide rules and paper charts, marking flight trajectories in grease on Plexiglas boards. The New York Defense Sector at McGuire Air Force Base in New Jersey was the first to get the Semi-Automatic Ground Environment (SAGE), which was enabled by Whirlwind. The Federal Aviation Agency (as it was known until 1967) hoped that simulations like Sky Shield, combining Air Defense Command with its own surveillance and air traffic control radars, would meld military command with FAA personnel through a program called SATIN (SAGE Air Traffic Integration). Under SAGE, the 600 daily civilian flights approaching the continent could now be checked against their authorized flight plans before they crossed the Air Defense Identification Zone, a buffer zone of airspace extending from the nation's borders and shores. If the flight path was main-

tained, the aircraft was, by definition, peaceful. If it

strayed, within a tolerance for weather and pilot error, identification was attempted by radio. If that failed, within minutes an interceptor would scramble for a visual check.

After detection, an enemy bomber would be engaged by long-range manned interceptors and next by a Bomarc missile; if it still survived, the bomber would fly into range of Nike-Ajax and Nike-Hercules missiles.

The Department of Defense announced in late July 1960 that on September 10 it would mobilize an unprecedented number of combat aircraft in a training exercise so vast that it could succeed only if civil aircraft did not interfere. "Airlines will have about eight weeks notice to adjust their schedules and notify their reservation holders," read the DOD news release. "Sky Shield differs from earlier exercises in that it will involve the whole radar and electronics system used in air defense. However perfect any system may be, it cannot be relied upon until it has been thoroughly exercised.

"About 2,000 defensive sorties will be flown," DOD predicted. "Exercise forces will not be armed with nuclear weapons. No live ammunition will be used in any phase of the exercise."

Some 1,000 commercial flights would be delayed or canceled in the United States, and 310 in Canada. Nearly 700 private business and pleasure flights would be squelched. In addition, 31 international carriers would delay arrivals or departures until the all-clear.

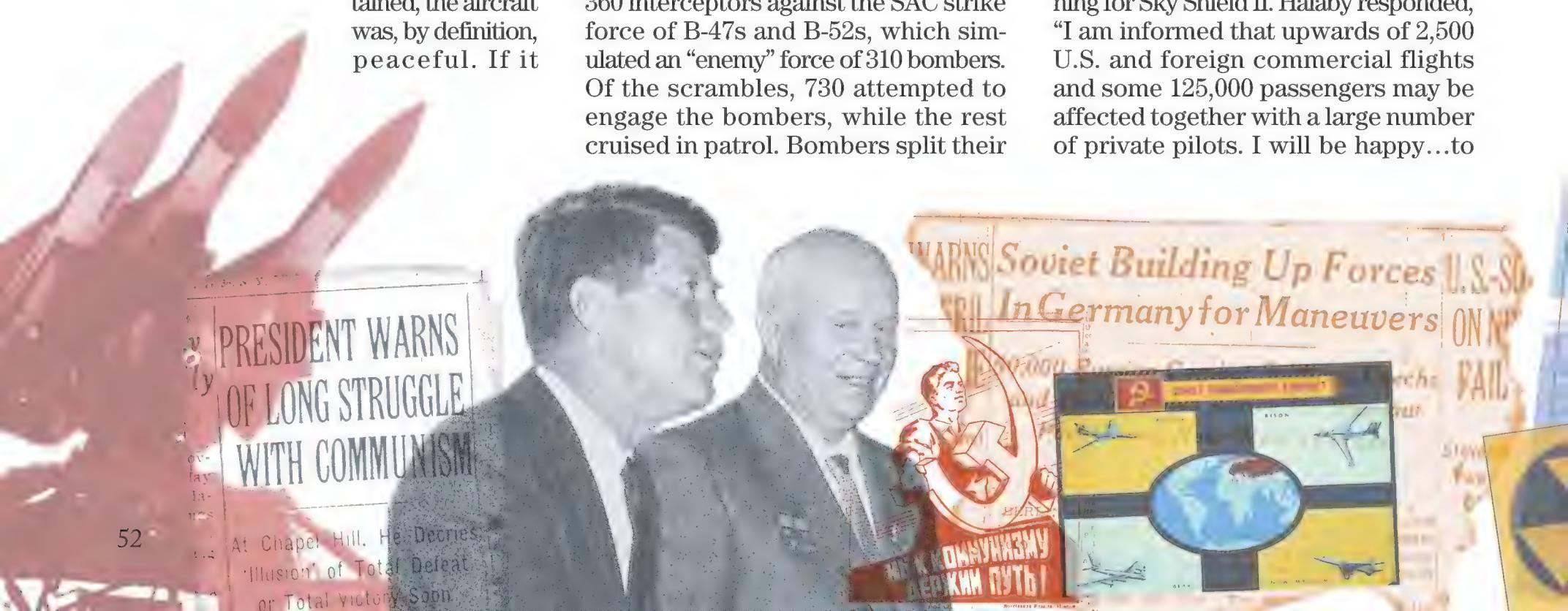
On September 10, not 2,000 but 1,129 fighter scrambles were flown by some 360 interceptors against the SAC strike force of B-47s and B-52s, which simulated an "enemy" force of 310 bombers. Of the scrambles, 730 attempted to engage the bombers, while the rest cruised in patrol. Bombers split their

missions between high- and low-altitude attacks with the two swarms converging on defenders. The missile force simulated engagements by 52 Bomarc, 254 Nike-Hercules, and 96 Nike-Ajax missiles.

In February 1961, William B. Becker of the Air Transport Association surveyed ATA members on how they had dealt with Sky Shield I: notifying passengers of the shutdown, juggling the rescheduled aircraft and crews, and changing reservations. "Estimated cost figures from only nine of the many air carriers affected totalled approximately one-half million dollars," he wrote. Reports from 14 airlines indicated that Sky Shield I, which had grounded commercial flights for six hours in the early morning, resulted in 182 flight cancellations and 100 schedule adjustments. Flying Tiger Line, which flew cargo at night, was hardest hit.

Nonetheless, Becker reported to the FAA, ATA members would support NORAD: "The airlines will continue to cooperate to the fullest extent where military requirements dictate the necessity. In the event that an exercise of the magnitude of Sky Shield is justified in the future, we strongly urge that a minimum of 90 days' advance notice be given. The exercise should be conducted on Saturday night-Sunday morning of a three-day holiday weekend."

Pleased with the cooperation from the FAA during Sky Shield I, NORAD's General Kuter wrote to thank agency administrator Najeeb Halaby, who was already elbow-deep in planning for Sky Shield II. Halaby responded, "I am informed that upwards of 2,500 U.S. and foreign commercial flights and some 125,000 passengers may be affected together with a large number of private pilots. I will be happy...to



inform these people of your appreciation for the contribution they are making toward the defense of the North American continent."

One channel Halaby had to pilots was the Aircraft Owners and Pilots Association, which published in the August 1961 issue of its *Confidential Newsletter* a paragraph about the continent-wide exercise. AOPA's more comprehensive *Pilot* magazine did find space to mention general details and grounding requirements in local time zones. "Don't Forget Sky Shield," it began. "If you've planned a flight for Oct. 14 or 15, better look at the clock before you take off."

More than 50 U.S. fighter-interceptor squadrons would participate, including those equipped with McDonnell F-101B Voodoos, Convair F-106 Delta Darts and F-102 Delta Daggers, Lockheed F-104 Starfighters, Northrop F-89J Scorpions, and Douglas F-4D Skyrays. Just over a thousand crews were on full alert. Across the continent some 150,000 airfield and flying personnel and 50,000 more in close support would also play a part, spanning NORAD, the U.S. Air Force, Army, Navy, Air National Guard, and the Royal Canadian Air Force. Navy picket ships and blimps bobbed off both coasts.

In Europe, NATO allies had already launched Operation Seven Pillars, a simulated strike of 40 atomic bombs followed by a numbing 22 hours of civil defense exercises. At coordinated times, defense officials opened envelopes containing simulated readouts of radiation levels, trying to determine the intensity of the blasts and their fallout patterns.

Like all NORAD exercises, the phases of Sky Shield II were

transmitted to Royal Canadian Air Force stations by secure media, but in case of intercept, not the details. Operations were given RCAF code names that were worthy of Maxwell Smart.

Planning conferences included Trusted Agents. Final pre-event checklists were dubbed Double Take

A or B. The harried, last moments: Fast Pace. The Go hour: Cocked Pistol. Various milestones were designated Big Noise A or B and so on, through Fade Out.

On October 14 at Naval Base Argentia, Newfoundland, WV-2 Super Constellations of the VW-11 and VW-13 squadrons were pulled from the hangar as their crews plotted flights for mid-level surveillance over the Atlantic barrier of the Distant Early Warning Line. Aloft, the U.S. Navy provided sea flanks to lengthen the DEW Line with radar-equipped WV-2s, nicknamed Warning Stars, along the coast.

At Building P-4 of Ent Air Force Base in Colorado Springs, General Kuter sat before ICONORAMA. Kuter was responsible for all air defense in the United States (except Hawaii), Canada, and the coasts of both nations out to 150 miles.

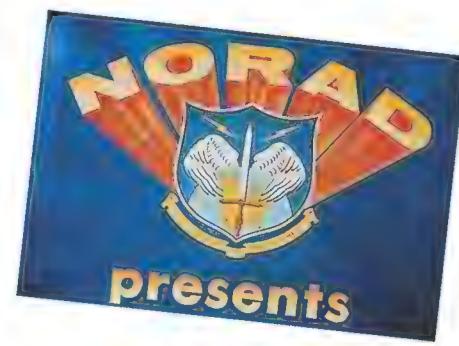
At Seymour Johnson Air Force Base in Goldsboro, North Carolina, Captain Roland C. Starke Jr. reviewed the crew assignment. The B-52G was filled with 215,000 pounds of fuel while his seven crew members boarded. As Pogo 22, Starke would flank Pogo 13 for three hours of flight in radio silence as part of the code-named White Cell in order to rendezvous



with one of three KC-135 Stratotankers, east-southeast of Newfoundland. Once refueled, the aircraft were to fly south toward Bermuda, then west for a simulated Soviet bomber run.

At McGuire Air Force Base in New Jersey, the war came down to single letters. Beginning at 1 p.m., the letters F for Friendly and K for Faker waltzed across the dull red of 106 cathode-ray tubes within the bunker's two-foot-thick walls. At full tilt, the Whirlwind II computer tracked 400 aircraft at once, sputtering 65,000 calculations every 15 seconds. Controllers pointed an aluminum light gun at each blip and squeezed, marking the blip P for pending. If the blip's track matched the expected flight plan, the P changed to F or K. "We've had it pretty heavy," Brigadier General Gilbert L. Pritchard, commander of the New York Air Defense Sector, told a cluster of reporters invited to McGuire. Pritchard said the simulated attack flown by B-47s, B-52s, and RAF Vulcans had been "pretty near continuous" since radar first detected an enemy at 1:45 p.m. "The attackers are coming over the top [the Arctic] and making end runs in off the Atlantic." Detected but unseen: Dark

Hawk missiles, Kennedy and Khrushchev, Soviet poster, NORAD brochure, Civil Defense icon, B-52, Curtis LeMay. Top: F-106 interceptors.



rain clouds enveloped New York City.

The wave of B-47s at low altitude showered pods of chaff—filaments coated with aluminum or zinc designed to overwhelm radars—while B-52s between 35,000 and 42,000 feet swept from the north through central Canada and diverged to the northeast and midwest population centers and along the West Coast as far as San Francisco.

In Colorado Springs, British Air Marshall Sir Kenneth B.B. Cross of the Bomber Command and Sir Wallace Kyle, chief of the Royal Air Force technical training command, sat with General Kuter. The Royal Air Force had provided 15 delta-wing Vulcan bombers to mix with NORAD forces, posing as Russian heavies. They topped the attacking force at 56,000 feet.

Shortly before 2 p.m., interceptors had sprung for the B-52s. Only the first Vulcan in the cell of bombers was detected by an F-101. At 2:02 p.m., the voice of an Air Force colonel reached the Boston Sector: "Gentlemen, we shot down our first enemy." Near Goose Bay, Labrador, the Vulcan became the first "kill" of Sky Shield II. The remaining Vulcans swept unmolested through eastern Canada to land at Stephenville, Newfoundland, for debriefing and bragging rights.

Captain Starke's B-52G and his cell of bombers refueled at 3 p.m., then turned southwest, toward their strike zone, a corridor between New York City and Philadelphia. The bombers flew in lateral formation, 10 miles apart, with Starke most northerly. He made radio contact with his left flank as late as 4:15 p.m. as the formation descended through clouds to 1,000 feet above the water.

On the east coast, jet fighters scored kills as far as 350 miles out in the Atlantic, the presumed maximum range

for a Soviet release of air-to-surface missiles. But most engagements were over or near major cities. "Sonic booms caused the customary surge of phone calls to newspapers, radio stations and police," reported the *New York Times*. Chaff fell on thousands of houses, fields, and factories, prompting more panicked calls.

At the airports holding open houses, the public and airport staffs partied on. Los Angeles International hosted 40,000 visitors by day's end, while workers seized upon the lull to complete the installation of a new air traffic control tower. At San Diego's Lindbergh Field, maintenance workers shut down terminal power to perform 12 hours of repairs in the dark corridors, while outdoor temperatures broke 107 degrees. Across San Diego at the Mission Valley Inn, Pacific Southwest and American Airlines held a crew luncheon and pool party.

At Chicago's O'Hare, Eastern, American, and Continental swung open the doors to their Boeing 707s and 720Bs. Trans World Air Lines presented its Convair 880, and United, its new Sud-Aviation S.E. 210 Caravelle twin-jet from France. At Chicago's Midway, American, United, and TWA displayed Douglas DC-6s and -7s. O'Hare began operating its \$4 million communications center. Following Sky Shield II, the cost of calls between Chicago exchanges and O'Hare was reduced from 15 to 10 cents for the first five minutes.

From 1 p.m. to 1 a.m. Eastern time, 2,900 commercial flights were canceled or delayed. At the three New York City air terminals, Newark, LaGuardia, and Idlewild, 955 arrivals and departures, affecting 26,800 passengers, were scrubbed.

The release of chaff ended one hour before the conclusion of the 12-hour exercise. Yet it fluttered down throughout the morning darkness, even as airliners began to resume service. Airliners stacked on taxiways conducted preflight checks; tower controllers nationwide directed flights to their runway thresholds to hold for the all-clear. At 1:07 a.m., after verification, a DC-8 departed Idlewild.

As of daybreak on Sunday morning, October 15, Captain Starke's B-52G from Seymour Johnson Air Force Base remained missing. A vast search triangle was set up 600 miles from New York. As late as 12:15 a.m. on October 17, a Coast Guard cutter chased a reported orange flare. The crew of eight was eventually presumed lost at sea, the only casualties of the three Sky Shields.

General Laurence Kuter was quoted in media ranging from *Air Force Magazine* to the *Chicago Tribune*, calling Sky Shield II "the greatest exercise in information analysis, decision-making, and action-taking in continental aerospace defense in all our history." But Kuter deflected calls for a box score, reiterating that Sky Shield's intent was, "by no means, a contest between offensive and defensive forces. Bombers presented themselves as targets and the object was not to 'shoot them down,' but to practice and train personnel in the use of the system." Sky Shield I had seen 1,129 sorties, but Sky Shield II bettered that by 50 percent.

Kuter added, "The many restrictions

Texas Tower; NORAD brochure; Eugene Zuckert, Najeeb Halaby, Alan Boyd, Curtis LeMay, Robert Lee; Pan Am 707 at Los Angeles.

SOURCES: ALBRIGHT COLLEGE NASA, LARRY RUSH/ARGENTIA NAVAL BASE, PINETREELINE.ORG, NASM, WIDEWORLD PHOTOS, ARLINGTON CENTRAL LIBRARY, OAK RIDGE NATIONAL LABORATORIES, USAF, JEFF BARNES, LOS ANGELES WORLD AIRPORTS

imposed in the interest of flight safety, and the leaving out of simulated nuclear detonations and other battle damage, served to distort many of the results." The Department of Defense refused to release an analysis or even to acknowledge that it had measured in any detail its radars, intercepts, and systems.

Quietly, NORAD produced an exhaustive report, presenting it to the Joint Chiefs of Staff before filing it in secure archives. A quarter-century later, the defense department ruled that as a bi-national command, NORAD could deny requests generated by the Freedom of Information Act. Finally, in 1997, most but not all of the Sky Shield results were declassified.

Had Americans known NORAD's conclusions, they might have ducked and remained covered. Nearly one-half of enemy flights at low altitude had escaped detection. Of those initially detected, 40 percent then eluded tracking radar by changing their formation shape, size, or altitude. All told, if Sky Shield bombers had been Soviet bombers, no more than one-fourth would have been intercepted.

During all three Sky Shields, friendly units had posed as the enemy. Yet the participants had acted too much like, well, the enemy: flying lower than preauthorized, and flying in patterns that deviated from their assignments, a practice that required scrambles of the reserve force to identify the "unknowns."

The remote radar stations, though, considered the most vulnerable of the far-flung system, survived every simulated ground attack.

The Distant Early Warning and the Ballistic Missile Early Warning System lines had been penetrated by enemy cells of up to four aircraft, despite flying inbound at the system's best tracking altitude, 35,000 to 40,000 feet. Low-altitude flights had been defined as anything below 5,000 feet, but NORAD acknowledged that a real

enemy would fly lower, where continental radar was weakest.

The SAGE system tracked less than one-third the total mileage flown within radar coverage. NORAD had prepared for an assault with advanced electronic countermeasures, but it was the low-tech chaff that degraded SAGE—to the point where manual tracking was required, leaving the enemy obscured until well within bomb-release lines.

In Sky Shield III, which ran for five and a half hours on September 2, 1962, NORAD and the FAA realized their full vision for the continental plan to safely ground civilian aircraft during a nuclear strike. At 3:05 p.m. Eastern time, the Air Force launched 319 T-33 light jets, 263 in the U.S. and 56 in Canada, from random and unannounced locations. As the alert horn sounded, FAA controllers hustled to get them to civil airports far from the metropolitan targets that were presumed to be under mushroom clouds. All T-33s were on the ground in Canada within 49 minutes, and in the United States within 72 minutes.

Before the all-clear had sounded, 1,800 scheduled airline flights in the United States and 130 more in Canada lay idle, as did 31 foreign airlines. The cost: \$1 million.

In 1963, NORAD planned to run Sky Shield IV. SAC officials objected, saying that they got better and cheaper training during focused, regional simulations. A round of limited, quarterly maneuvers called Top Rung began in fiscal year 1964.

On September 25, 1961, President John Kennedy had stressed the gravity of the Communist nuclear threat to the United Nations General Assembly. But Kennedy added that it was terrorists and fanatics, more than superpowers, that threatened national defense: "Terror is not a new weapon. Throughout history it has been used by those who could not prevail, either by persuasion or example. But in

evitably they fail, either because men are not afraid to die for a life worth living, or because the terrorists themselves came to realize that free men cannot be frightened by threats, and that aggression would meet its own response. And it is in the light of that history that every nation today should know, be he friend or foe, that the United States has both the will and the weapons to join free men in standing up to their responsibilities."

Communist or terrorist threat, the Sky Shield exercises had made a mere dent in airline operations. The public's support of the military was unwavering, and the advance notice of the exercises allowed plenty of time to make alternate travel plans.

Sky Shield came at a time of record airline growth and revenue for passenger jet travel, which was in its infancy, but record low profits, because of fare wars. Airlines merged, cut costs, and called for a five percent fare hike. Eastern Airlines president Malcolm MacIntyre spoke for the industry in September 1961, telling a New York press luncheon that "the bottom of the business had dropped out" and calling 1961 "a very bad year, the biggest red-ink year barring none."

The entire U.S. civil fleet would not be grounded again until September 11, 2001—and then for days instead of hours, and with devastating financial and psychological costs.



TRANSPORT NEWS: WE SKY SHIELD TEST

Air Defense Exercise Will Ground All Airliners

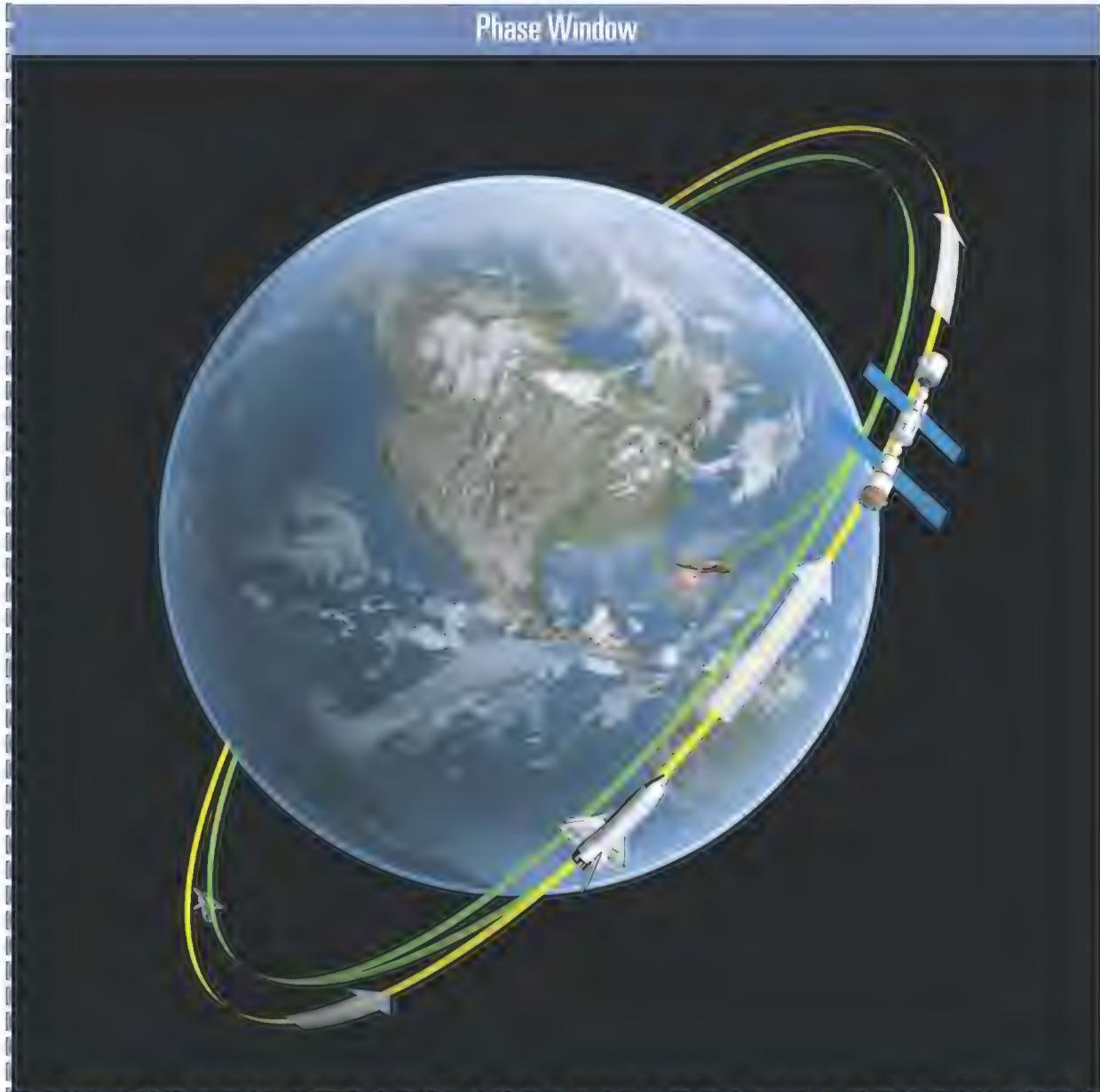
Approximately 1,800 passenger craft will be grounded for a period this week. Operations during a simulated nuclear attack will be suspended in the United States. The Defense Department knows that

airline traffic will be suspended. P.M. East tomorrow to Du



by Eric Adams | Illustrations by John MacNeill

Launching a rocket into space is a bit like jumping off a moving merry-go-round. You wait until you see the exit coming around, factor in the time it'll take you to coil up and launch yourself, the speed you're already traveling, the merry-go-round's general dimensions, and your air time after leaping—and then jump at just the right moment and scoot out the gate. If you wait until the exit is right in front of you, you'll overshoot it and have to turn around and walk back. If you jump as soon as it comes into view you'll have to walk (a bit sheepishly) that extra 15 feet.



Space shuttle launches work on the same principle, just on a much larger scale and with many more variables. Engineers calculate how much time they have—down to the minute or even second—to launch and reach a target for rendezvous. This determination is called the launch window, and it has become such a critical part of spaceflight operations that NASA now devotes teams of engineers to the task of getting it just right. "Before the space shuttle, you had only a few guys figuring out when to launch, how to rendezvous, and when to reenter," says NASA flight dynamics officer Phillip Burley, who works on shuttle missions at Johnson Space Center in Houston. "But the shuttle is much more complicated, and it has broken down into teams of specialists for each phase. I specialize in rendezvous—making sure the spacecraft gets precisely where it needs to go once in orbit."

His colleague Richard Jones, also a flight dynamics officer, or FDO (pronounced "fido"), specializes in the ascent, and the two, with other team members, work closely to factor in all the variables and plan the mission's timing from start to finish. Basically,

Launch Windows

Jones explains, a launch window is the overlap of two time periods, known as the plane window and the phase window. When the space shuttle is to rendezvous with the International Space Station, engineers calculate when the orbital path of the ISS passes directly over or near the latitude and longitude coordinates of Kennedy Space Center in Florida—that's the plane window (the orbit is the edge of a circular plane that passes through the center of Earth). "If it passes directly over Kennedy Space Center, that's our optimal time for launch," Jones says. "If it passes a few miles to the east or west, that's okay but it will require some additional steering. And that takes additional fuel and adds stress to the external tank, which we want to minimize."

When visualizing plane window scenarios, it's important to remember that Earth rotates at 1,035 mph, but an object's orbit is fixed in space. That means that the orbital path of the ISS passes over a different part of Earth on each 90-minute, 17,000-mph orbit—the station's "ground track" is always sliding to the west. The ground track of the ISS may cross near Kennedy Space Center on one orbit, but when it comes back around 90 minutes later, Earth will have rotated and the or-

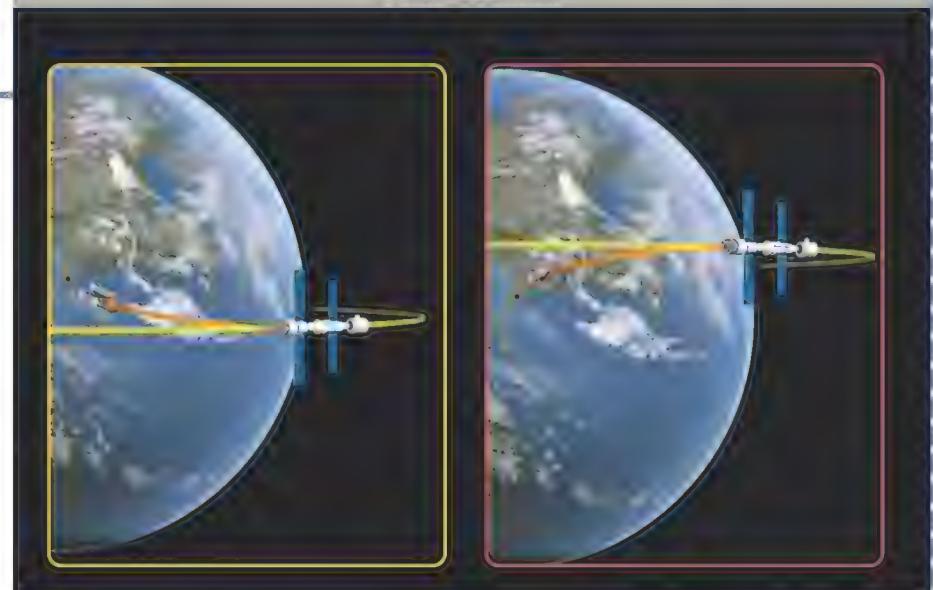
bit will cross at a point about 1,000 miles due west (see "ISS Ground Track, below"). The result: There is only one plane window per day for a rendezvous mission, because it takes about 24 hours (Earth's circumference is ap-

proximately 25,000 miles, divided by a rotation rate of 1,035 mph) for the target orbit to return.

The other component of the launch window calculation is the phase window, the period during which launching the shuttle will place it in line behind the ISS and on schedule to rendezvous at a specified time, usually three days after the launch (see "Phase Window," previous page). Fuel constraints limit the launch window to between 2.5 minutes and 10 minutes for a rendezvous. Any longer and the shuttle will not have enough fuel to catch the station. (The shuttles that have held on the pad for hours before launching didn't have a scheduled rendezvous.)

Though there may be many plane and phase window intersections over a several-week period, there are other variables that might further reduce the number of potential launch windows. These include the crew's sleep cycles (so a rendezvous is not scheduled "at night"), where the external tank and the solid

Plane Window



rocket boosters will be dropped off (never over land), wind characteristics on launch day, possible abort scenarios, certain types of mission-specific requirements, or even the desired reentry and landing times.

When the window is finally selected, the launch calculations can be further adjusted by computers even during the final seconds of the countdown. If, because of delays or other schedule changes, the launch occurs earlier or later in the 10-minute launch window, the orbiter will have to steer east or west to match the shift in the orbital path of the ISS (see "Plane Window," above).

Finally, though the launch window coincides with the space station's orbital path, launch isn't necessarily timed for the exact moment the station flies over Kennedy. Engineers factor in multiple orbits over several days before the meeting. A rendezvous could happen on launch day, but the crew needs time to adjust to weightlessness and prepare for their mission, so the orbiter takes a lower orbit at higher speed, possibly lapping the ISS, and then burns its engines to increase altitude, slow down, and creep up on the station from below and behind on the third day. The shuttle's stealthy approach may sound sneaky, but don't worry. The station crew usually knows it's coming.

ISS Ground Track



IT BEGINS WITH THE PUSH, USUALLY AT, SAY, 20,000 FEET AND MAYBE 50 MILES FROM THE TARGET. THE PILOT RUNS THROUGH A CHECKLIST WITH THE RIGHT-SEATER, THEN THROWS A SWITCH ON THE LEFT SIDE OF HIS FLIGHT CON-

TROL PANEL, ENGAGING THE TERRAIN-FOLLOWING RADAR.

The TFR noses the airplane over into a 10-degree, half-G dive, hurtling aircraft and crew toward the ground at more than 8,000 feet a minute.

One of the first aircraft to be equipped with terrain-following radar was the F-111, the swing-wing tactical fighter-bomber that made prime contractor General Dynamics infamous for a while in the 1960s. When it started service with the U.S. Air Force in 1967, it followed the terrain of the Nevada desert near Nellis Air Force Base. Today the terrain is the scrubby hill country around Royal Australian Air Force Base Amberley in the Queensland province of Australia. The RAAF Strike Reconnaissance Group at Amberley

is now the only combat unit in the world operating F-111s.

In the dive, the pilot throttles back a little to keep from go-

The Aussie Pig is big—weighing as much as 114,300 pounds fueled and loaded—and a pain to maintain.



The Plane with no Name

by William Triplett | Photographs by Chad Slattery

In Australia,
they call it
the Pig.



ing supersonic and then, with a pistol-grip control under the left canopy railing, sweeps the wings back to 44 degrees.

The F-111 was also the first operational aircraft with variable-geometry wings. When configured with the minimum sweep, 16 degrees, the wings provide enough lift for a heavily armed fighter to take off and land on short airstrips. With the wings fully swept at 72.5 degrees, the F-111 is a hot rod capable of Mach 2.5. At cruise altitude, the pilot typically sets the wings at 26 degrees of sweep for maximum range and fuel efficiency.

Once the aircraft has descended to 5,000 feet, the ride gets more interesting. The TFR pushes the nose down even more, to 12 degrees, increasing rate of descent to 12,000 feet a minute.

"A bit counter-intuitive, isn't it?" says Air Commodore Dave Dunlop, head of the Strike Reconnaissance Group at Amberley, where all 35 of the RAAF's F-111s are based. "Very unsettling the first time you do it," says Squadron Leader Matt Sibree, one of the younger pilots. Apart from watching instruments to make sure things are operating as they should, the pilot is just along for the ride—as is the navigator, the RAAF's term for the right-seater. In the U.S. Air Force it's a weapon systems operator, or WSO (pronounced "wizzo"), who also has navigation duties, just as RAAF navs also operate weapon systems.

The TFR finally levels the aircraft at a pre-determined altitude, usually at about 1,000 feet. The crew can then begin "stepping down" at 200-foot in-

crements to as low as 200 feet for the run to the target. The twin turbofans are propelling the aircraft at between 600 and 700 mph. The pilot sweeps the wings accordingly—10 percent of airspeed in knots, meaning anywhere from 51 to 60 degrees. With a sweep of greater than 45 degrees, though, the spoilers can't be used, thus severely limiting the amount of roll that can be introduced.

It's a wild ride—something that could also be said of the F-111's entire career.

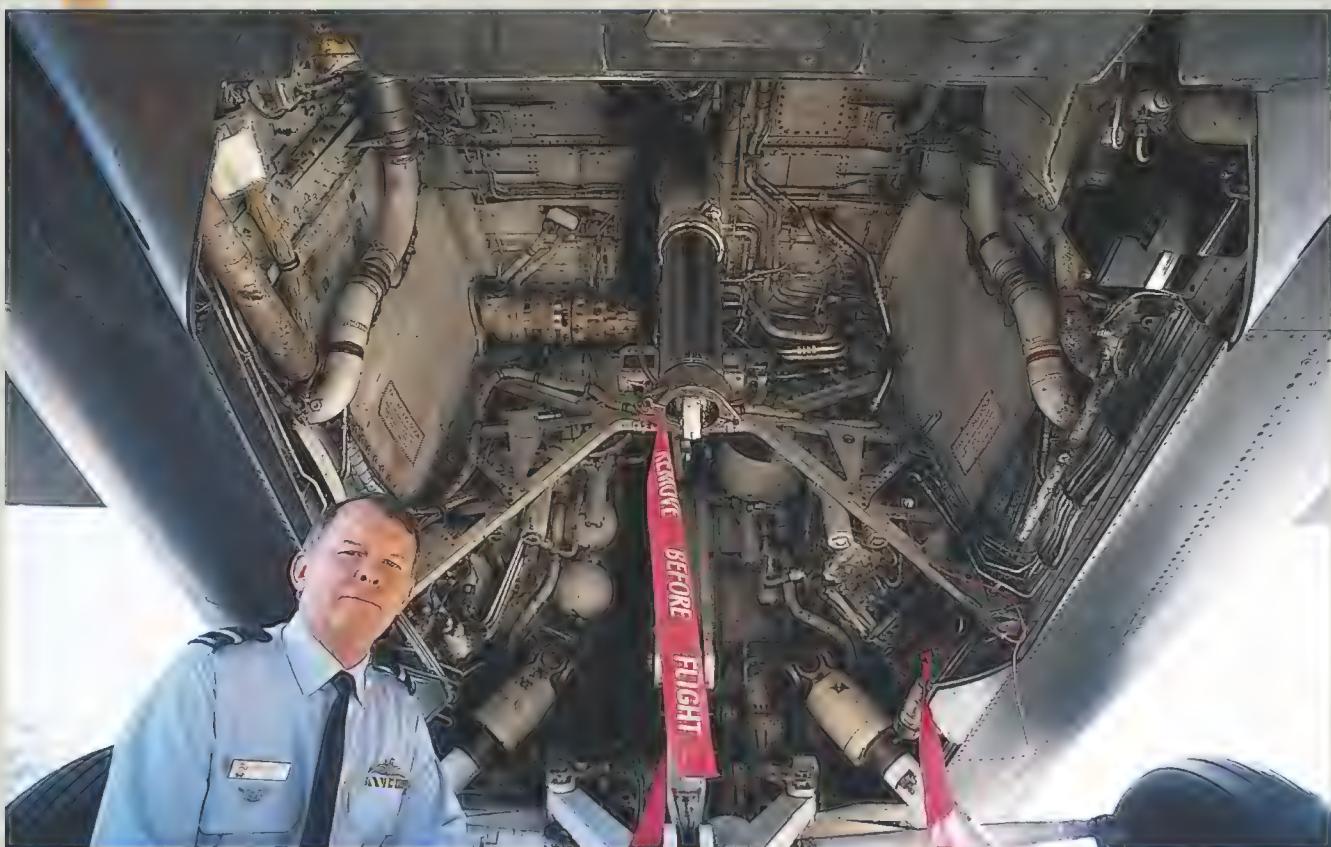
One-elevens served 30 years in the U.S. Air Force, eventually distinguishing themselves in several roles, but their reputation has never fully recovered from the controversy surrounding their tragic introduction. The aircraft may be unique among U.S. fighters in that it was not christened with an official nickname—a name like "Super Sabre" or "Thunderchief," the names of the F-100 and F-105, which the F-111 was designed to replace. When the U.S. Air Force retired its last -111s in 1996, officials at the ceremony finally bestowed on the airplane the name pilots had been unofficially calling it for years—"Aardvark," chosen because the airplane's extended nose makes it resemble the long-snouted pig-like African creature.

Aussies, who take pride in their tradition of plain talk, simply call it "Pig." It is a term of endearment, spoken with great respect because in Australia, as in its later years in U.S. service, the -111 has matured into the role it was designed to fill.

"So what's the airplane good for?" asks RAAF Wing Commander and veteran Pig driver David "Doc" Millar. He's leading a briefing at Amberley for novice crews. A giant map of Australia flanks him at the front of the room. On it are several large circles whose centers are RAAF air bases dotting Australia's northern coastal areas, and the circles—each representing the 3,500-mile operating range of combat-ready F-111s—stretch hugely toward Southeast Asia. Millar nods toward the circles, saying with pride, "And that, gentlemen, is why we're still flying a jet that was designed in 1963. Nothing else can do that."



F-111 engine inlets were redesigned twice because airflow disturbances caused compressor stalls. The final version increased the separation between the inlet and fuselage, increased the inlet area by 10 percent, and featured aerospike 18 inches longer than the originals. Below: The aircraft's landing gear was also strengthened by the time Australia took delivery. Air Commodore Dave Dunlop believes the F-111 is now the right plane for the job.



In training exercises, F-111s have carried 8,000 pounds of bombs for 1,500 miles—at low level for 300 of them—without airborne refueling. They can do it at any time of day or night and in any kind of weather. Millar's right. Nothing else can. But why did Australia ever feel a need for such capability?

In the years following World War II, as the British government began withdrawing from its former Asian colonies, Western leaders fretted over communist expansionism. The fretting rose to the level of military action in June 1948, when Chinese communists in the Malay peninsula murdered three wealthy rubber plantation owners, setting off a terrorist campaign to overthrow the British-supported government there. The RAAF joined in the counterattack from an air base in Singapore, and the fighting continued sporadically until 1960.

By that time, Western thinking had crystallized into the so-called domino theory, which held that one country after another would fall to communism if no one challenged it. Australia was nervous about neighboring Indonesia, whose president, Achmad Sukarno, was vague about whether he'd oppose or welcome communist influence. (Indonesia's political instability resulted in a failed 1965 coup dramatized in the film *The Year of Living Dangerously*.)

In a grab for headlines, Australian politician Arthur Calwell claimed in 1963 that the Indonesian air force could bomb almost any city in Australia and that the RAAF had no capability to reciprocate. Although the remark was primarily political exploitation, it struck a nerve. The RAAF's strategic bomber at the time, the English Electric Canberra, was an old design—the first jet bomber to be manufactured in Great Britain—and it had limited range. From an Australian base, it was unable to reach Indonesia or any other part of Southeast Asia, where communism was beginning to get a foothold.

"Replacing the Canberra had been the RAAF's top priority for a number of years," wrote RAAF historian Alan Stephens in the book *Going Solo: The Royal Australian Air Force 1946–1971*. "In a reflection of classic air power



Elegant it's not, but beneath the awkward exterior, the F-111's avionics—and twin Pratt & Whitney TF30-P-3 turbofans—make it one fearsome pig.

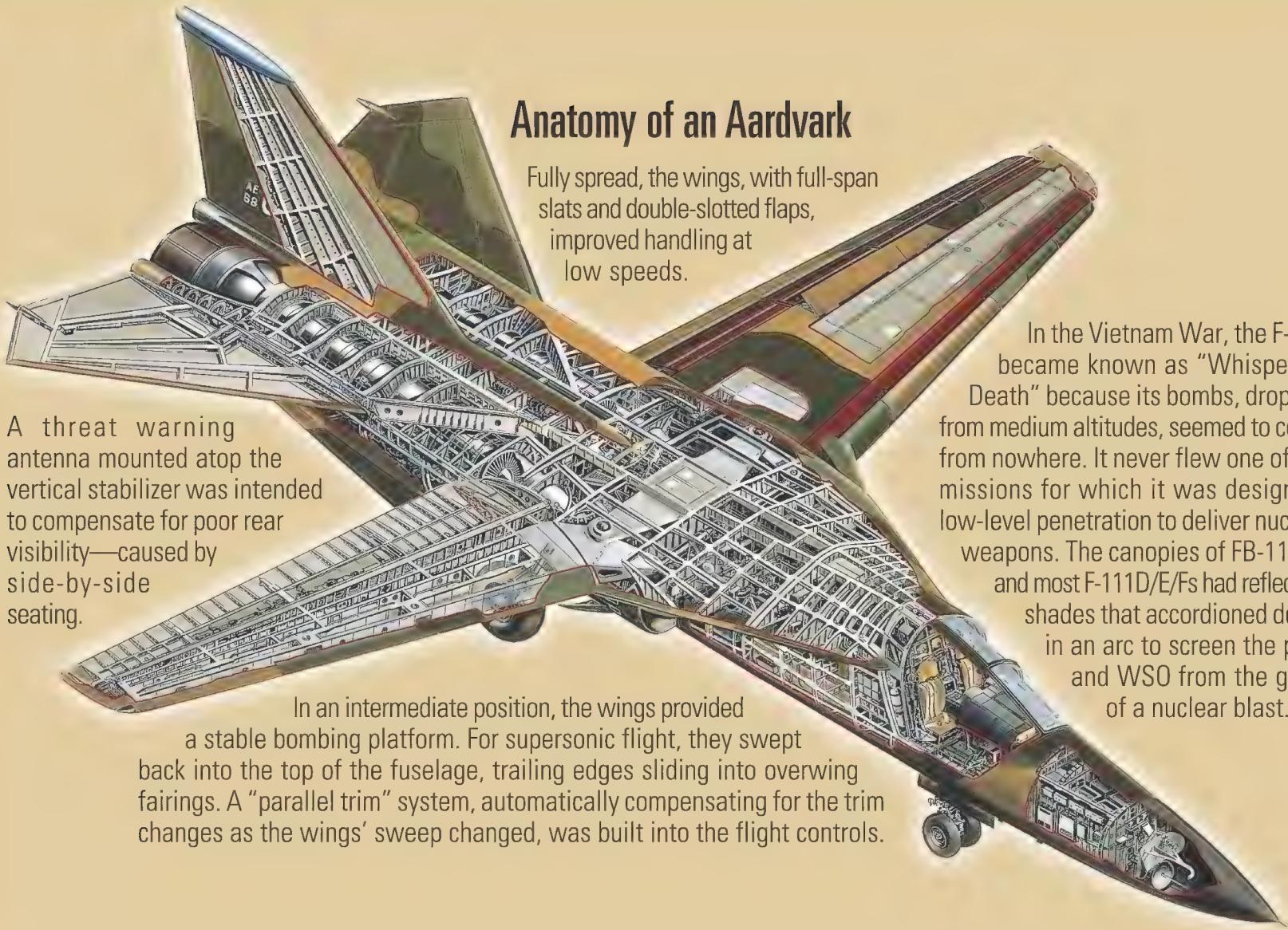
doctrine," Stephens comments today, "the need for a new strike/reconnaissance aircraft was expressed in terms of taking the initiative in the air by destroying the enemy's air force on the ground, then turning the RAAF's offensive air power against other targets, both strategically and in direct support of the army and navy."

The strategy called for an aircraft with an attack capability that was both versatile and precise. At first the RAAF considered buying the TSR.2, a new warplane the British Aircraft Corporation was developing. But the TSR.2 never went into production, and the Aussies turned their attention to the F-111.

Today any threat to Australia is still theoretical, but the RAAF continues to look warily toward the north. "Because any threat to Australia would likely come through the sea and archipelagic region to the north, we need a long-range, multi-role capability to operate in that environment," says Wing Commander Brian Walsh of the air attaché staff at the Australian embassy in Washington, D.C.

Says Stephens: "It's also noteworthy that when the Interfet [United Na-

The F-111 turned out to be a revolutionary aircraft, exemplifying two great aeronautical advances. The first was the breakthrough in high-speed flight made possible by the maturation of turbojet technology. The second was an explosive growth in the use of electronics.



JOHN BACHELOR



RAAF navigator Aroha Fifield is a specialist in the guidance and weapons systems that make the F-111 valuable. That big brute breathing down her neck is an F-111G.

tions peacekeeping] force deployed to East Timor in 1999, a detachment of F-111s was sent to the RAAF's base at Tindal, near Darwin. While the aircraft weren't used, the message was crystal clear and was understood by those for whom it was intended."

"Being an island continent, most of our defense is based on the perception that any potential enemy would have to cross the sea to get to us," Dunlop says. Thus the RAAF wanted a few custom features on their -111s, beginning with anti-ship weaponry. They also liked the longer wings on a Navy version, the F-111B, and a fighter-bomber variant, the FB-111A. General Dynamics designed the F-111C exclusively for the RAAF. It was the only model ever to be capable of firing a Harpoon anti-ship missile. In October 1963, when the aircraft was still being designed, the RAAF agreed to pay \$100 million for 24 of them; the service recently announced that it plans to continue operating its fleet in both strike and reconnaissance roles until the year 2020. Few would have predicted that the F-111 was destined for such a long career.

Near the end of the 1950s the USAF Tactical Air Command put together its requirements for a future attack aircraft. TAC wanted an airplane that could do Mach 2.5 at altitude and Mach 1.2 at low level, where, if necessary, it could fly 400 miles without slowing down. It would have to be able to take off and land on airstrips as short as 3,000 feet and to fly un-refueled across the Atlantic Ocean with an ordnance load of up to 30,000 pounds.

Meanwhile, the U.S. Navy also happened to need a new fighter—to be based on aircraft carriers and serve as fleet defense. The coincidence turned out to be one of the most unhappy and expensive chapters in the history of interservice collaboration. Shortly after John F. Kennedy took office in 1961, Secretary of Defense Robert McNamara tried to save the new administration money by ordering the Air Force and the Navy to develop one aircraft that would carry out both missions. In 1969 the Navy finally abandoned the joint venture, dubbed TFX for Tactical Fighter Experimental; by then, McNamara's idea had ended up wasting \$377 million.

From the start, the two services banged heads over just about everything. The Navy wanted side-by-side seating for the two-man crew, long-range radar, long loiter capability at upper altitudes and subsonic speeds, and a gross weight of under 50,000 pounds for carrier operations. The Air Force wanted tandem seating and, focusing on low-level, supersonic capabilities, some sort of terrain-reading radar—not yet invented—and a gross weight of 75,000 pounds. The only point of agreement was the need for a variable-geometry, or swing, wing: Both services wanted maximum lift for short takeoffs, along with high-speed capability once airborne. (Although the F-111 was the first operational aircraft to use a variable-geometry wing, the concept was not new. The Bell X-5 experimental aircraft tested the configuration in the early 1950s, and those tests were based on research reports “imported” from Germany at the end of World War II.)

General Dynamics built the F-111A for the Air Force, and Grumman built the F-111B for the Navy. Both versions had the variable-geometry wing, turbofan engines, side-by-side seating, and a crew escape module (instead of the usual ejection seats). But only seven Bs ended up being built. The Navy withdrew from the program after concluding that the aircraft could never be brought under weight restrictions for carriers. But having gathered experience in producing swing-wing aircraft, Grumman later embarked with the Navy upon another program that proved far more successful—the F-14 Tomcat.

The Air Force soldiered on with the F-111A, which turned out to be a revolutionary aircraft, exemplifying, according to the U.S. Air Force historian Richard P. Hallion, two great aeronautical advances then under way. One was the breakthrough in high-speed flight made possible by the maturation of turbojet technology. The second was an explosive growth in the use of electronics, which led to the development of the first “systems” airplanes. “The first category of those airplanes were the air defense interceptors,” says Hallion. “But the second category was the so-

phisticated air-to-surface attack aircraft, and coming out of that was the notion of all-weather attack. There were two great early systems airplanes in the air-to-surface arena. One was the F-111 and the other was the [U.S. Navy’s] A-6.”

The electronics package in the F-111 included the hair-raising terrain-following radar, built by Texas Instruments and integrated with a targeting radar, an inertial navigation system, and other sophisticated avionics. The result was an unprecedented autopilot that would enable high-speed flight at extremely low altitude at night and in all kinds of weather. The pilot and weapon systems operator could be guided with electronics to strike a target they couldn’t see. At least that was the plan.

The F-111A saw its first action with the 428th Tactical Fighter Squadron in Vietnam during the spring of 1968. Three crashed within a month of the first combat sortie, killing two crews. A fourth crashed at Nellis Air Force Base in Nevada that May. The Air Force suspected that in at least two of the crashes, the cause was TFR failure. At the same time, -111s were suffering engine compressor stalls, during which airflow reverses because of pressure fluctuations at the inlet. The Air Force grounded the aircraft and, along with NASA and Gen-

eral Dynamics, worked to redesign the engine inlets.

The sink rate of a variable-sweep-wing aircraft on final approach was a challenge to pilots. “We lost one airplane and one crewman at Edwards Air Force Base as a result of that,” says Hallion. Then during spin-and-departure trials, the test model went out of control and crashed.

The RAAF took delivery of its first F-111C in July 1968. During static testing in September, a wing failed, and General Dynamics suspended delivery of the 23 remaining aircraft.

“The F-111 was a very difficult airplane for the Air Force to deal with,” says Hallion with a sigh. The critical areas were the pivot joint, where the wings attach to the fuselage, as well as a fitting called the wing-carry-through box (WCTB), wherein the loads from the wings pass through the fuselage. Hairline cracks were causing catastrophic failure of the pivot joints, while an investigation of the WCTB traced the failures to defective manufacturing. Over the next several years all USAF F-111As (and the RAAF’s one C) were retrofitted with strengthened pivot joints and properly manufactured WCTBs. The compressor stalls were fixed by expanding the inlet and inserting a new adjustable inlet device that maintained proper airflow into the compressor.

Even experienced air crews train three times a month in the simulator to hone communication as well as handling skills.



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With the wing removed, Corporal Brendon Ketchell polishes nicks on the upper wing pivot lug.



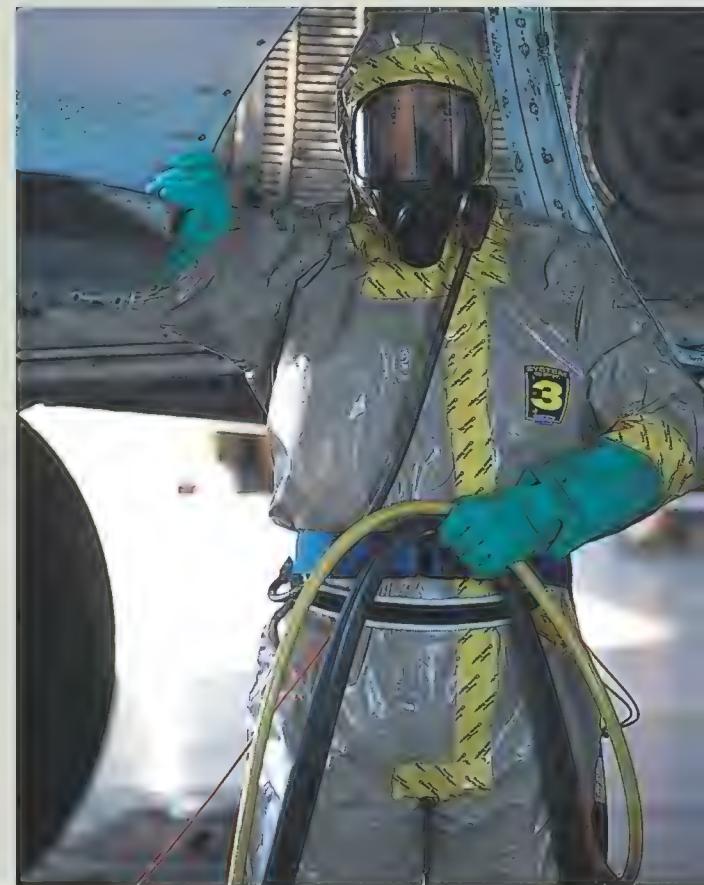
But the modifications were driving up the price of the aircraft, first from the original \$4.5 million per unit to \$6.3 million, then later much higher.

Some in Congress took to calling the F-111 "McNamara's Flying Edsel." In Australia critics disparaged it as "the Flying Opera House," linking it with the Sydney Opera House, then under construction and suffering from massive cost overruns and delays. The RAAF didn't take delivery of its remaining 23 F-111Cs until June 1973. Four were later converted for reconnaissance and designated RF-111Cs.

Even after its U.S. redeployment to Southeast Asia in the fall of 1972, bugs continued to infest the -111's avionics, but the aircraft nonetheless began to prove itself—flying in weather that kept other aircraft on the ground, hitting targets using only instruments. The Air Force flew F-111s on some 4,000 combat missions in Vietnam and lost only six aircraft.

Once outfitted in the 1980s with new avionics—specifically the Pave Tack targeting system, which uses a high-quality infrared video camera to acquire targets and an integrated laser designator to guide bombs to them—the F-111 could live up to its original promise. Of the 8,000 laser-guided bombs that the Air Force dropped during the 1991 Persian Gulf war, about half were dropped from F-111s. One-eleven crews also perfected the technique known as "consecutive miracles," in which one laser-guided bomb blows open the front of a hardened shelter and another, coming seconds behind, slams deep inside for a direct internal hit.

In the mid-1990s the RAAF bought 15 F-111Gs—formerly a nuclear-capable version built for the U.S. Strategic Air Command, which had originally designated them FB-111s. The service had also acquired four A models and converted them to Cs to replace aircraft that had crashed. One of these, in Australian service as A8-109, was flown on a number of missions to North Vietnam, according to Doc Millar, and suffered battle damage to the fin. "It was described in early F-111 literature as a bit of a dog," says Millar, "but in current RAAF service it is one of the best aircraft in the



Contractor Barney Barnard dons a protective suit before climbing into a fuel tank to reseal it.

fleet." Of the total 43 F-111s acquired, 35 remain in the RAAF's fleet: 17 Cs, 14 Gs, and the four recce Pigs, all flown by the two squadrons of the Strike Reconnaissance Group.

Crews love the airplane. They unanimously swear by the smooth ride of the -111 at low level, comparing it to a Cadillac on air. "At 200 feet and 600 knots in an F-18, you know it," says RAAF Group Captain Geoff Brown, a strapping older pilot who's relatively new to the F-111. "It's bumpy and the jet doesn't like it. But it's a great ride in a one-eleven—the most comfortable thing I've ever flown so low to the ground."

"It almost seems like the Earth is moving beneath the aircraft, rather than the other way around," says Jim Rotramel, a former U.S. Air Force WSO. "The things that stick with you are the impressions. Flying down a steep valley in the Scottish highlands, telling the pilot that I'm seeing in the radar high terrain on his side of the airplane and him craning his neck way up to see where the ridge stopped and the stars started."

A daylight run to a target can also be memorable. The TFR sports a pair



USAF

Loaded with four 500-pound Paveway II bombs and a Pave Tack pod, this U.S. Air Force F-111F is ready for target practice. In the Persian Gulf War the aircraft was prized for its precision weapons delivery.

of miniature radar dishes in the radome that scope 15 miles in the distance and then inform the autopilot of obstacles to avoid. Laterally, however, those dishes are only interested in what stands within four degrees of the aircraft's flight path. Trees and towers often whoosh past, only a matter of feet from the wingtips.

Night runs are therefore less distracting, unless you happen to be flying in one of Australia's southern test ranges, which are scored by deep gullies and canyons. "There are a couple of routes there where you can drop down into a gully and have a reasonably steep face next to you," says Dunlop. "The TFR doesn't see it. But out of the corner of your eye you'll catch the rotating beacon being reflected off the cliff side, and that'll get your attention, believe me." (Dunlop once flew with a navigator who, later asked by a local reporter what the crew does when the TFR takes over, replied, "We watch the goddam thing to make sure it doesn't kill us.")

The nav, meanwhile, is "in the feedbag"—head down, eyes glued to the multifunctional display, working to line up the target with the crosshairs of the attack radar, which can see

some 30 miles ahead. "It can be nerve-wracking," says Aroha Fifield, one of the RAAF's growing numbers of female navs. Fifield, who is 23, has a bright, friendly smile that you would never associate with the ability to put a 1,000-pound laser-guided bomb in your lap from five miles away.

A toss—essentially lofting a laser-guided bomb—wracks more nerves than other attack profiles because, Fifield notes, "there's less time. You work the attack radar all the way up until you clear the pilot to release the weapon." The pilot then goes into "pedal-pull-pickle" mode—that is, disengaging, or "pedaling off," the TFR in order to pull the aircraft into a hair-flattening 25-degree, 600-mph, 4-G climb. The pilot then hits the "pickle button," which clears the weapon system to automatically release the bomb—usually about five seconds after the climb begins.

With the bomb now airborne, the hardest and most dangerous work has to be undertaken. The nav has at most 30 seconds before the bomb hits the ground. All his or her attention must be focused on the instruments: the infrared scanner to find the target, and the aircraft's laser, which must be held on the target until the

bomb hits. All the while the pilot is still climbing, and the aircraft, now also banking as much as 90 degrees, is highly vulnerable to ground fire or air attack. "But it's the busiest time for flying the aircraft," says pilot Matt Sibree, "so there's no time really to think about it."

The job is tougher at night. Forty percent of the Strike Reconnaissance Group's training missions are low-level night sorties. Night attacks require "absolute faith in instruments, computers, and terrain-following radar," says Doc Millar. They also demand split-second coordination between pilot and navigator during the run to the target, when the pilot is monitoring the TFR and principal flight instruments and the navigator is in the feedbag. "Each has to know when to expect 'climb' [or] 'dive' commands from the TFR and what to expect from each other," Millar says. "This is before you add the complexity of formation, ground-based air defenses, air threats, weather, et cetera."

The complexities can lead to what air crews call "task saturation," something several American crews of the 48th Tactical Fighter Wing experienced in April 1986 during the first offensive air operation conducted by



Once outfitted in the 1980s with the Pave Tack targeting system, which uses a high-quality infrared video camera to acquire targets and an integrated laser designator to guide bombs to them, the F-111 could live up to its original promise.

Maintainers swarm an F-111G at RAAF Base Amberley. In the 1980s F-111Cs were modified with Pave Tack laser designation pods (left), carried in the weapons bay, which gave them dead aim.

the U.S. Air Force since the Vietnam War. Stationed at Lakenheath Air Base near London, the 48th provided an attack force for a U.S. raid on Libya, which was a retaliation for Libyan-sponsored terrorism against the United States. Of the 20 F-111s that attacked, only four scored hits. Though one aircraft was lost (cause unknown) and the raid failed to kill Libyan leader Muammar Qaddafi, it clearly caused him to lower his profile and turn down the volume of his inflammatory anti-American rhetoric. An unpublished account of the raid (the author requested anonymity) suggests what an F-111 cockpit is like during combat:

“Remit 32 [the aircraft’s call sign] had a very experienced pilot paired with a relatively new but promising WSO. The spectacle of massive quantities of anti-aircraft artillery, surface-to-air missiles flying one way, HARM [high-speed anti-radiation] missiles fired by Navy A-7Es in response flying the other way, and the unexpected use of parachute flares by the Libyans, turning night into day, rattled the WSO. When the pilot realized

they had gone too far without beginning their toss maneuver, they aborted their bombing run and roared across Tripoli at rooftop level.

“Remit 33 had a moderately experienced pilot and a highly experienced WSO. Without functioning TFR, they approached the target at 1,000 feet, using their radar altimeter until the parachute flares made it possible to fly visually. Then their Pave Tack pod malfunctioned, so the WSO did what WSOs had done before they had Pave Tack pods. He did a radar toss, which put their bombs squarely in the barracks courtyard, although they didn’t cause any significant damage. The malfunctioning Pave Tack pod did manage to capture the launch of an SA-8 missile at these intrepid aviators, which impressed them to no end when they saw it during their debrief.”

Maintaining “situational awareness” is the most crucial survival skill in combat and the one that RAAF training most emphasizes. It means that every moment, pilot and navigator together have a clear picture of

the terrain, obstacles, and threats.

Some crew members would prefer tandem seating to make it easier to see threats from behind. But the majority of pilots see advantages to having someone next to you. Side-by-side seating offers fast visual communications about actions that would otherwise have to be confirmed verbally and thus take more time when time is extremely tight and concentration on systems vital.

"[Low-level night attack] is probably the most dangerous and complex form of aviation after night carrier operations," says Millar. "We have killed five percent of our air crew over the years in this flight regime."

In 28 years the RAAF has lost eight -111s, five in fatal crashes. The last four were at night and involved the military euphemism "controlled flight into terrain." "One went in at a 40-degree angle at 500 knots," says an RAAF pilot who asked not to be identified. "Not a pretty sight."

Though investigations haven't yielded conclusive proof of what caused any of the -111 crashes, Millar says the Strike Reconnaissance Group believes all were the result of human error, either "loss of situational awareness or failure of crew coordination." The group has since started a new program, Crew Resource Management Training, to improve crew coordination. And before any mission takes off, a complete risk assessment of the flight profile is mandatory, including reviews of technical and operational airworthiness.

Because of the advanced age of the fleet, ensuring airworthiness is a challenge for the SRG's maintenance personnel. The wing pivot points and the wing-carry-through boxes are presenting problems again: Although General Dynamics corrected the earlier weaknesses, the steel is starting to show its age. RAAF mechanics say it's a low-carbon alloy; despite high tensile strength, it's very brittle and prone to corrode over time.

Given the swing-wing design (that is, no wing spars to distribute loads, as a conventional aircraft would have), the loads are heaviest on the areas of the wings nearest the pivots and the WCTB. As the steel ages, those wing

areas are more susceptible to stress cracks. To prevent that, mechanics have to tear down a wing (first allowing its fuel cells to dry completely). Then with a small piece of 320-bit aluminum oxide paper on the end of a finger, they reach inside and scratch away, re-profiling internal support assemblies to ease the loads on the area. "You usually spend a couple days just on one area," says a wing shop mechanic.

Other maintenance headaches involve air ducts, which are mounted outside the landing gear housing but with the bolts mounted inside the housing. The ducts break frequently and need to be replaced. "To get at them, you stand on the speed brake, put your arm through [the gear assembly], and twist around, and you're turning blind back there," says Sergeant Michael Tenaglia, who maintains engines and airframes. "You can't see it because your back's to it, so you hold a mirror up and look back over your shoulder."

Replacement parts aren't always available. Even though the RAAF spent about \$100 million to acquire spares from the U.S. Air Force after the Americans retired their fleet, maintenance crews have sometimes had to refurbish old parts and have also cannibalized five F-111Gs to

keep the rest of the fleet flying.

Avionics too show their age. The TFR, now in its third generation of technology, still fritzes out occasionally. And while the C models are now equipped with nearly infallible GPS receivers, the Gs still use inertial navigation, the software for which frequently needs updating, when it doesn't fail altogether.

Yet for a country that spends \$6.9 billion—less than two percent of its gross domestic product, according to most recent figures—on its military, it is far cheaper to maintain an older aircraft than to replace it with something new, which would cost billions of dollars. Besides, says Dunlop, as well as about a dozen other RAAF officers, what else is out there?

Nothing like the F-111. Not really maneuverable enough to be called a fighter and several tons short of a big bomber's carrying capacity, the -111 nevertheless has its own special set of capabilities. Jim Rotramel puts it in perspective: "During my [final] flight I wanted to see how far we could go at low level, so we zig-zagged across the width of the state of New Mexico for an hour and a half at 550 mph. Our internal fuel weighed more than a combat-loaded F-16."

No wonder it was tough to find the F-111 an appropriate name. 

Squadron Leader Matt Sibree with tail art expressing the squadron spirit.



Block That Nuke | Bruce Berkowitz

In a world of dead treaties and downed office towers, the United States needs a practical missile defense now more than ever.

Now that President George W. Bush has given the Russians formal notice that the United States will withdraw from the 1972 Anti-Ballistic Missile Treaty, the country and Congress will finally have a serious discussion about missile defense.

The Department of Defense began working on a new missile defense system after North Korea fired a test rocket in August 1998 that had the potential to reach U.S. territory.

Unfortunately the Clinton administration's approach—the so-called National Missile Defense system—was more Rube Goldberg than Robert Goddard. Because it insisted on compliance with the 1972 ABM Treaty (which limited the United States to a single interceptor base at Grand Forks, North Dakota), NMD relied on long-range missiles that would have to travel halfway around the world to hit their targets in mid-flight. To add to the challenge, the interceptors were to be "kinetic kill" weapons, which destroy incoming warheads by smacking them head-on. It would be hard to design a tougher engineering problem.

In mid-flight, Intercontinental Ballistic Missile warheads are cold, dark targets in the vastness of space, less than three feet in diameter and traveling at four miles per second. To work, an interceptor would need to play defense the way Derek Jeter plays shortstop for the New York Yankees. It's not impossible. One prototype NMD interceptor hit a dummy target rigged with a radar beacon last August, and a second test succeeded in December. Let's just say it's a sporty proposition.

It's too bad that missile defense has become less of a military requirement

against an emerging threat than a test of political manhood, with pundits and politicians trying to demonstrate how much they support or oppose arms control. The United States faces a real problem that will only get worse: the proliferation of long-range missiles. If the military doesn't act now to counter the threat, someday soon people will ask the kinds of questions they've been

Instead of a single rival superpower armed with 1,600 ICBMs, today the United States faces a dozen or more countries that might fire missiles from any number of directions.

asking about airline security since September 11.

A lot has changed. Instead of a single rival superpower armed with 1,600 ICBMs aimed over the North Pole, today the United States faces a dozen or more countries that might fire missiles from any number of directions.

Most of these countries are looking for a way to discourage the United States from interfering in "their" neighborhood. If they could lob a nuke into the general vicinity of, say, San Francisco, would this country be as ready to help its friends in the Pacific Rim or Middle East? Recall how hard it was

to muster public support for sending American forces to the Persian Gulf in 1991 or the Balkans in 1999. These decisions will be even harder if Americans think intervention puts them directly in the line of fire.

The United States needs missile defense if it wants to remain a world player and assist its friends abroad. Most of these countries are democracies, like Japan, South Korea, Taiwan, and Israel. Others are important trading partners, like Saudi Arabia. All of them live in tough neighborhoods, and would have a tougher time if the United States seemed less able to drop in.

And if that does not worry you, remember that many of the countries that support terrorism happen to be the same ones trying to develop long-range missiles. The fact that a country like North Korea, which can hardly feed its people, can cobble together an ICBM ought to tell you something. Missile technology has always been hard to monitor and even harder to control.

Some naysayers argue that we should worry less about potential incoming missiles and more about whether an adversary can smuggle a nuke into the United States or slip a bomb into a U.S. port aboard a freighter. But that's not the problem.

The Soviet Union and the United States both developed suitcase nukes for their commando forces during the cold war. Both countries knew, however, that the fastest, surest way to deliver a nuke to a target is via missile. Today, America's potential adversaries know this too, which is precisely why they're developing ICBMs.

Besides, homeland security is rarely an either/or problem; the answer is more often "all of the above." The United States needs better intelligence, a beefed-up Customs Service and Coast Guard, and more cooperation among government agencies. Along the way the country also ought to improve com-

missile defense

munications among all levels of government and the private sector. Threats today can come from any direction, take many forms, and strike from far away. Missile defense is one part—but an important part—of a larger picture.

To be sure, intercepting ICBMs isn't skeet shooting, and developing effective defenses will be challenging. That's why the United States needs to take a practical approach. One way to start is to look at programs that tackled problems about as complex as missile defense and that eventually succeeded.

Most of these programs did not put all their bets on one horse but developed several technologies simultaneously. The Manhattan Project developed two atomic bomb designs, for example. Even more important, program planners deployed less-than-perfect systems quickly to gain some real-world experience. Later, they fixed the rough spots. Look at how the Army developed helicopters: The first ones were a joke, and the second-generation ones not much better.

Even more important, successful programs tried to make the problem easier to solve, not harder. Imagine if John Kennedy had told NASA engineers that the United States was going to the moon, but that they could not use a lunar module and had to land the entire Apollo spacecraft. Oh, and no failures or the program will be cancelled. That's why abandoning the ABM Treaty was so important. It prevented engineers from even considering working on new ideas that might have simplified the problem.

So here's a practical plan for missile defense. First, have modest expectations. Don't try to build the perfect global defense system right out of the box. Start with systems that already have a track record, like our existing sea-based air defense missiles and land-based tactical missile defense systems; gradually expand their range and reli-

ability. Remember, for small, bull's-eye countries like Japan, Taiwan, and Israel, an improved tactical defense would be, in effect, a national system.

Second, be realistic. Avoid "silver bullet" solutions. Use a combination of systems that let the United States take its first shot as soon as a missile takes off, and combine these with other weapons that let the military take a second or third shot and provide a last-ditch defense near the target. "Boost phase intercept" is not exactly easy—you have to react quickly and the atmosphere gets in the way—but a missile one minute after launch flies at a quarter of the speed of a warhead in mid-flight, and is ten or twenty times larger.

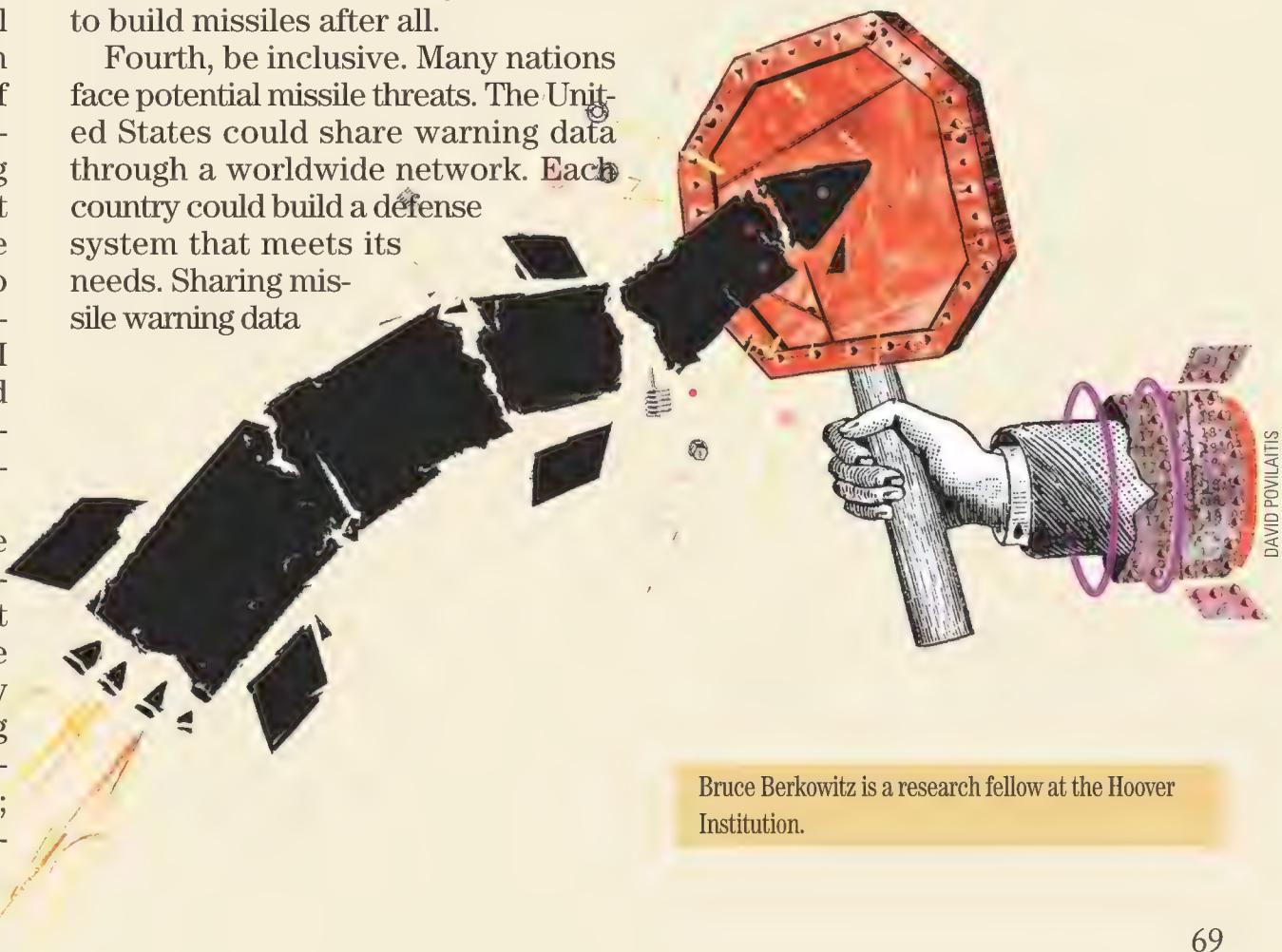
Third, be incremental. Focus first on improving the range and accuracy of existing tactical defensive systems. Aim for, say, a 50 percent success rate when the system is first deployed. If the United States raises the bar by eliminating the free shot that exists today, some of its adversaries may decide not to build missiles after all.

Fourth, be inclusive. Many nations face potential missile threats. The United States could share warning data through a worldwide network. Each country could build a defense system that meets its needs. Sharing missile warning data

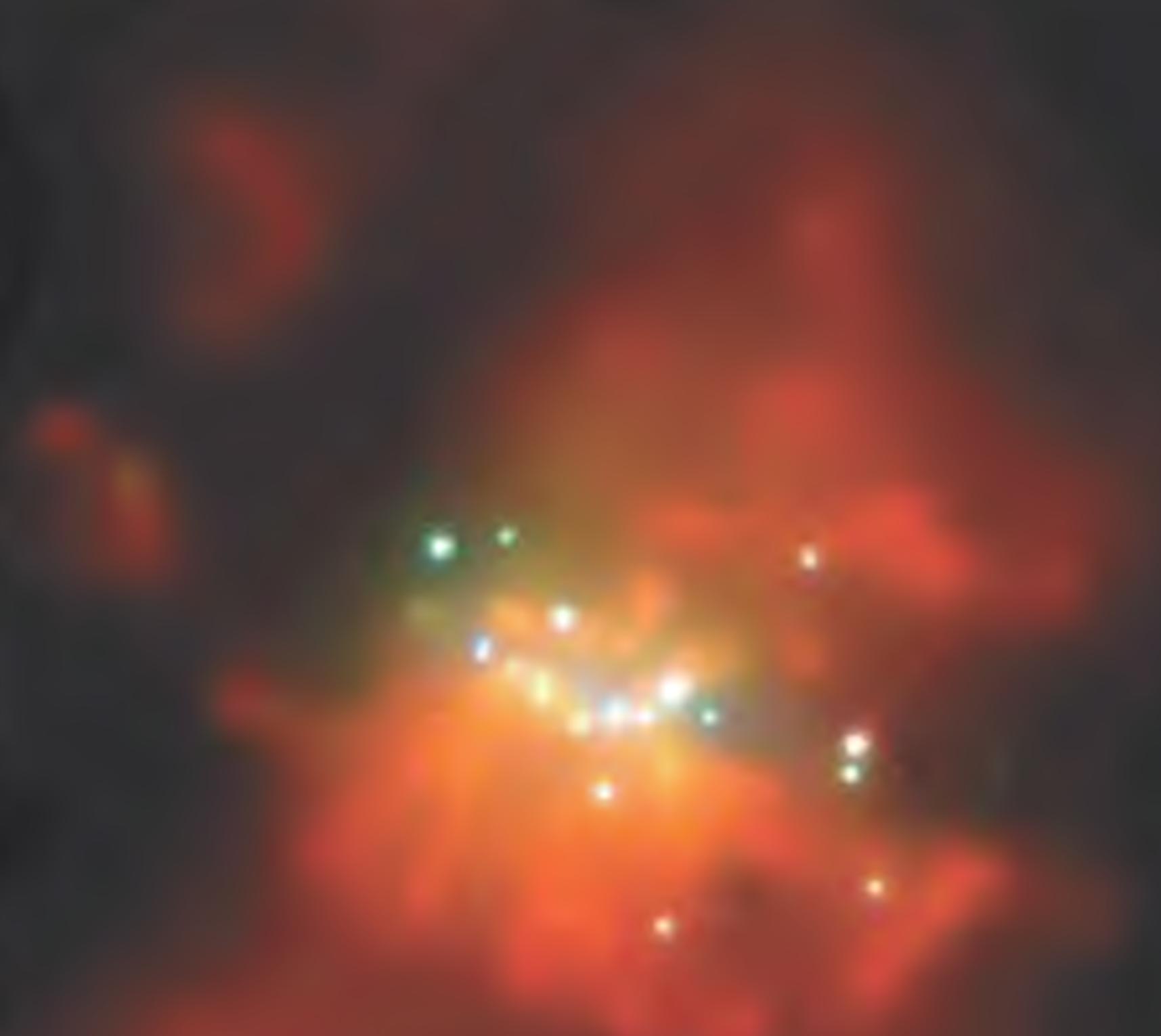
fits perfectly with our post-September 11 policy to share intelligence and law enforcement data. The only ones who could object to such transparency are those who want to threaten missile attack.

And finally, don't fool yourself; effective missile defense won't be cheap. For that matter, the bill for improving border security, customs, intelligence, and all the other components of homeland defense will be expensive too. One way to make room is to phase out much of our Soviet-era military force faster. Does the United States really need a new heavy artillery system like the Army's Crusader, which costs an estimated \$12 billion? Does it really need scores of bases that were originally designed to mobilize and support a bigger, lower-tech military force?

Missile technology won't go away. It takes a lot longer to develop defensive missiles than offensive missiles, which is why the United States needs to build practical defenses today.



Bruce Berkowitz is a research fellow at the Hoover Institution.



X-ray

**The Chandra X-ray Observatory opens the book on
the high-energy universe.**

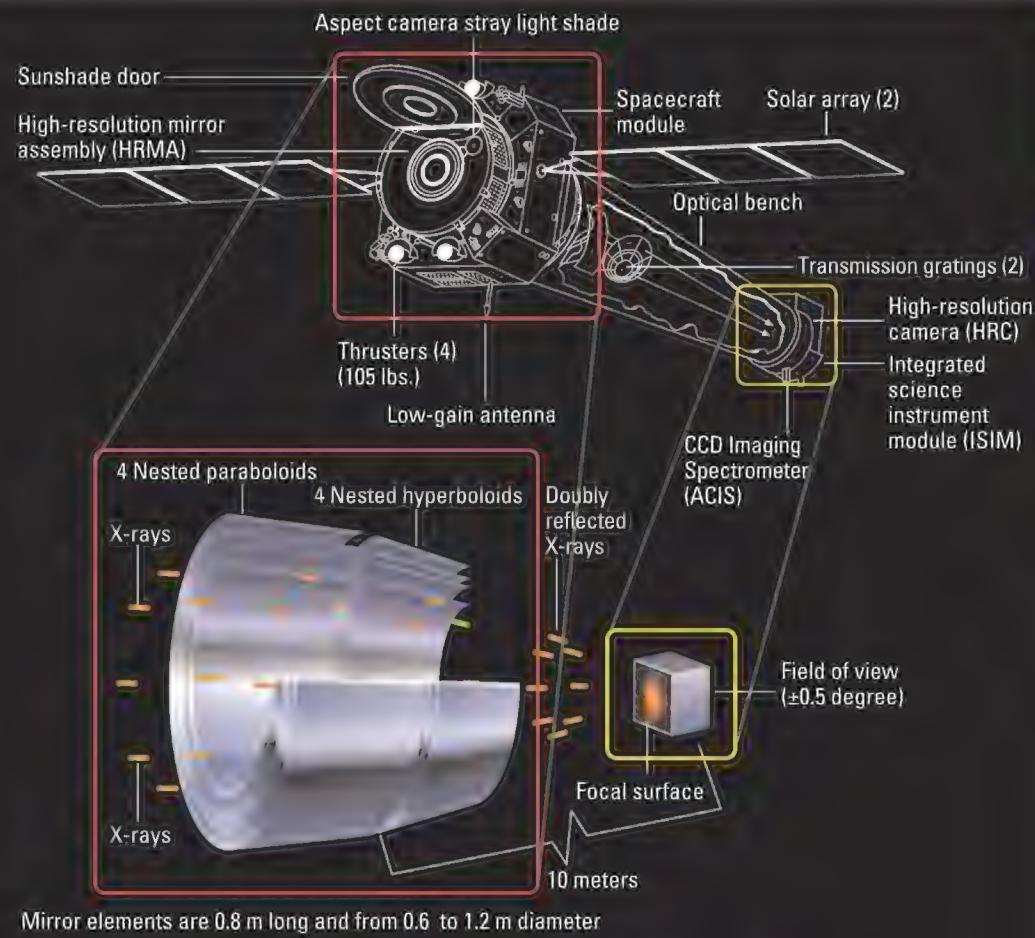
Sitting in

his Cambridge office, a silver scooter leaning discreetly against one wall, Claude Canizares ponders catastrophe. The director of the Massachusetts Institute of Technology's Center for Space Research and associate director of the Chandra X-Ray Center knows it's a jungle out there, but he isn't talking about the high-tech tumult of Cambridge. What's on his mind today are fierce conflagrations like supernova Cassiopeia A, solar-system-spanning outbursts that would flash-fry soft human flesh in milliseconds. These and other incandescent churning found in the universe's hot spots fascinate Canizares and his colleagues.

eyes

by James S. Schultz

The brightest central object in this image of galaxy M82 is an extremely powerful source of X-ray emissions, likely a black hole.



CXC/TRW

Chandra's orbit ranges from 6,200 miles from Earth to 86,900 miles, a third of the way to the moon (above). Mirrors are assembled at Eastman-Kodak (below, left).



EASTMAN-KODAK

How Chandra Works

Chandra's cylindrical mirrors deflect X-rays into instruments at the back of the telescope. One of these is the High-Resolution Camera, which contains 69 million tiny lead oxide glass tubes. X-rays striking the tubes cause electrons to be released toward a wire grid that measures each electron's arrival time and position. This enables the camera to "paint" a high-resolution image of the object.

TOP: CXC/TRW; MIDDLE: CXC/D. BERRY

be detected only with extremely sophisticated sensors. That's why astronomers eager to study these pathologies depend on the Chandra control center, which receives a steady stream of data from the orbiting Chandra X-ray Observatory. At the center, a staff of 50 oversee observatory operation, monitoring telemetry in real time, for one to two hours, three times every 24 hours. Transmission is two-way; operational commands are sent to the telescope based on observation targets proposed by astrophysicists, and then the spacecraft downloads to the center in 30 minutes the data it has collected during the previous eight hours. The operators convert the data into images that the scientists who requested the observations can study and disseminate to other

"Cosmic catastrophe is a central part of what happens astronomically," the astrophysicist says. "The phenomena are just so compelling at these high energies and temperatures. It's a peculiar aspect of human nature: Explosions, collapses, and cataclysmic events are fascinating in and of themselves. X-ray astronomy is the study of these sudden changes—the 'cosmic pathology,' if you will."

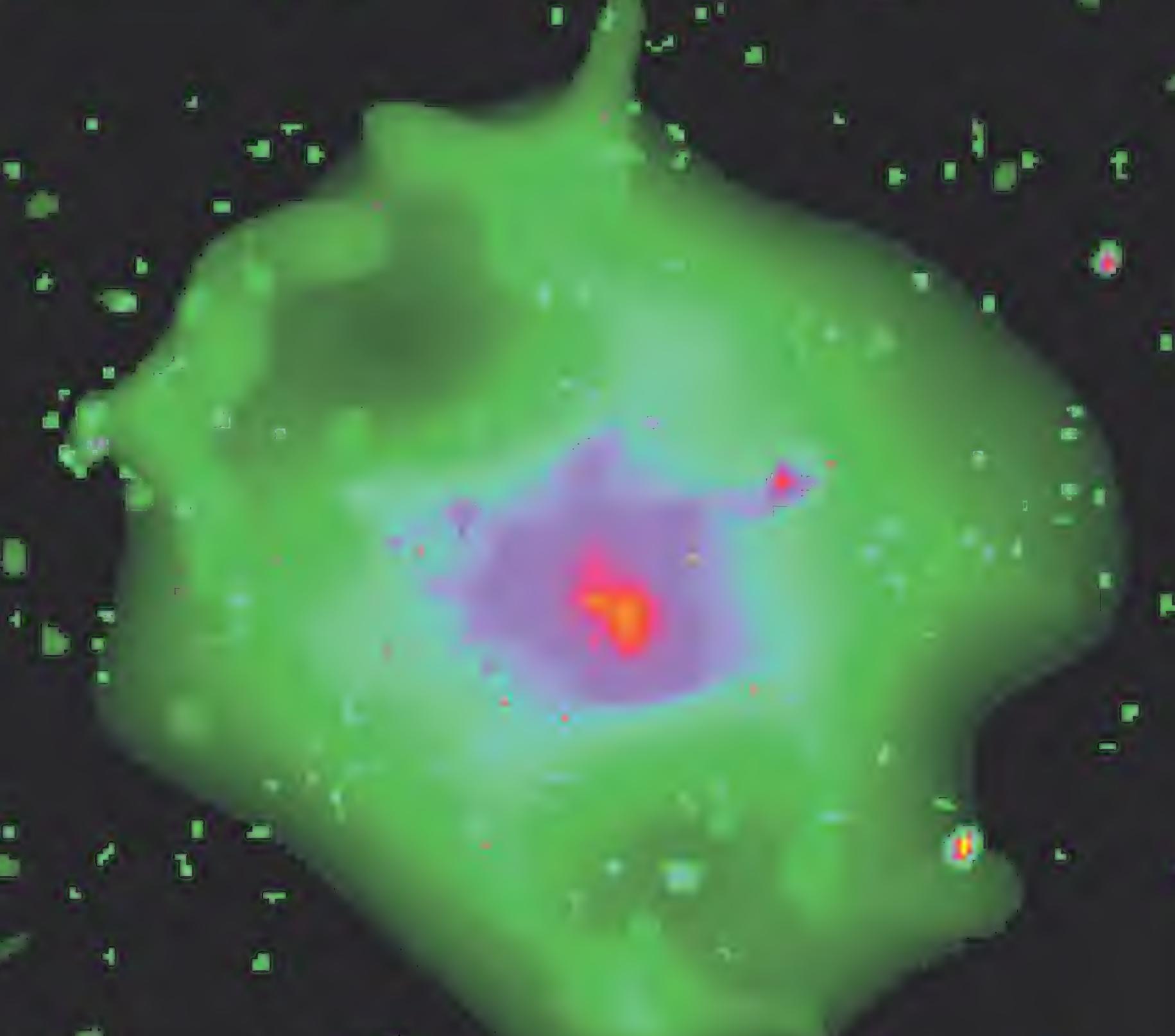
The X-ray universe is all around us, but is invisible to the naked eye and to conventional ground-based optical telescopes; X-rays in space can

researchers around the world.

With its launch aboard the space shuttle on July 23, 1999, and subsequent deployment, Chandra became the third in a series of NASA's Great Observatories, joining the still-operational Hubble Space Telescope and the Compton Gamma Ray Observatory, which operated from 1991 to 2000, as orbiting instruments designed to peer ever deeper into the cosmos. Thanks to Chandra's sensitivity and sophistication, X-ray astronomy appears to have entered an era of unprecedented discovery. In particular, Chandra, which is named for the late Indian-American Nobel laureate Subrahmanyan Chandrasekhar, one of the foremost astrophysicists of the 20th century, is helping scientists to understand how black holes devour matter and energy.

At a September 2001 press conference, astrophysicists announced an example of their recent key discoveries: the cause of a violent, rapid X-ray flare observed in the vicinity of the supermassive black hole suspected to reside at the center of the Milky Way. A team of scientists led by MIT's Frederick Baganoff detected the flare while observing a source of strong radio emissions known as Sagittarius A*. The source suddenly emitted X-rays at a prodigious rate, roughly 45 times the expected rate. After three hours, X-ray intensity declined to pre-flare levels. The team concluded that the rapid

Humankind owes its very existence to stellar eruptions that give off material that drifts through the void, enriching the stellar medium and seeding planets, perhaps even life itself.



Small galaxy groups such as HCG 62 may serve as cosmic building blocks. The two cavities that sit symmetrically opposite each other (upper left and lower right) in the hot (purple and red) X-ray-emitting gas are likely due to jets of particles emitted from one of the central galaxies.

NASA/CFA/J. VRTEK ET AL.

A Luminous Mind

Celebrated scientists, Greek and Roman gods, noted explorers:

Names of the illustrious and esteemed have long been given to spacecraft on missions of exploration. "NASA's challenge to [the Chandra team] was to find a name that would also speak to people's imaginations," says Chandra X-Ray Center director Harvey Tananbaum. "So we sponsored an essay contest."

The 1998 contest to rename the Advanced X-Ray Astrophysics Facility, or AXAF, drew 6,000 entries, with suggestions ranging from "Isaac Asimov" to "Marie Curie," the Polish-born French physicist who coined the word "radioactivity" in 1898. One name seemed a favorite of many entrants: that of astrophysicist Subrahmanyan Chandrasekhar. The six-member selection committee agreed, and the orbiting telescope's official moniker became the Chandra X-ray Observatory.

Born in Lahore, India, on October 19, 1910, Subrahmanyan Chandrasekhar would eventually be called Chandra by friends and colleagues, a Sanskrit word meaning "moon" or "luminous."

Studying first in India and then in England, Chandrasekhar was

trained as a physicist before emigrating to the United States in 1937, where he taught at the University of Chicago for the remainder of his life. There he proved a popular teacher—shepherding 50 students to Ph.D.'s during his career—and prolific author, writing 10 books on a variety of topics, including the relationship between art and science.

Among his most notable works was the discovery of what is now known as the Chandrasekhar limit, which defines the physical limits on the mass of a white dwarf star. Earth's sun appears destined to become a white dwarf once its nuclear energy is entirely spent billions of years from now. By contrast, stars more massive either explode into novas or supernovas, leaving behind neutron stars, or collapse to form black holes.

In 1983, Chandrasekhar won the Nobel Prize for his studies of the physical processes important to the structure and evolution of stars. For 19 years, Chandrasekhar also served as editor of the *Astrophysical Journal*. He continued to write and teach at the University of Chicago until his death on August 21, 1995.



AP

Unlike optical light, X-rays are absorbed by Earth's atmosphere and thus can only be detected by instruments riding above the life-sustaining gaseous envelope that girds the planet.

rise and fall were compelling evidence that the emission resulted from matter, probably gas from a captured star, falling into the black hole.

Black holes have long stymied researchers. In the aftermath of the publication of Albert Einstein's theory of general relativity, German astronomer Karl Schwarzschild developed the concept of black holes as concentrated regions of extreme gravity. Astrophysicists calculated that black holes would form when massive stars several times larger than the sun die (smaller stars would evolve into less compressed bodies, such as white dwarfs or neutron stars).

Thus, when a massive star exhausts its internal thermonuclear fuels, it becomes unstable, gravitationally collapsing inward and becoming compressed to a particularly small—only a few kilometers in diameter—volume of super-high density. Nothing, not even light, can escape the powerful gravitational field produced by the black hole. Once snagged by the event horizon surrounding the singularity, black-hole-captured energy and matter appear to vanish completely from the universe.

Matter stripped from a companion star by a black hole can form a flat, pancake-like structure, known as an accretion disk. As material spirals to-

ward the center of the disk, and eventually into the event horizon, it is heated by the immense gravity of the black hole, causing it to radiate X-rays, which are produced when matter is heated to millions of degrees. It is a point of no return, beyond which no one can say definitely what occurs. "We still don't understand the basic physics of gravity," says Stephen Murray, director of the High-Energy Astrophysics Division of the Harvard-Smithsonian Center for Astrophysics in Cambridge. "Are there wormholes, time warps, or can you extract information from the other side of an event horizon? We don't yet have nearly enough information to conclusively address such speculations."

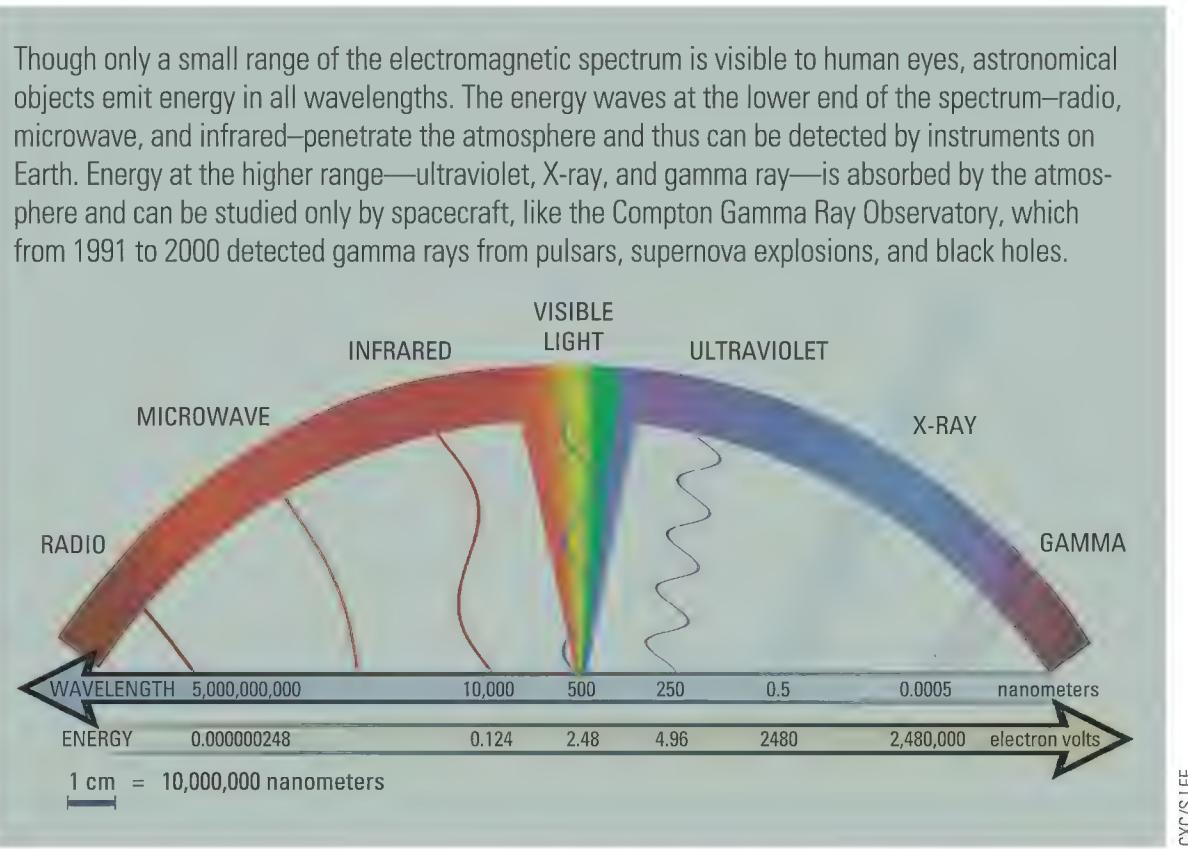
With Chandra, the existence of black holes could at least be indirectly proven. Since 2000, the telescope has conducted observations that provide additional detail about black holes. For example, on September 12, 2000, astronomers announced that the observatory had pinpointed near the center of galaxy M82 an apparent black hole that could represent a missing link between smaller stellar black holes and the supermassive variety found at the centers of galaxies. The M82 black hole has the mass of at least 500 suns concentrated into a region about the

size of our moon. Such a black hole would require unique conditions for its creation, such as the collapse of a "hyperstar" or the merger of many smaller black holes.

Chandra's power comes from its ability to make analytical sense of X-rays. Unlike ordinary light, X-rays are absorbed by Earth's atmosphere and thus can be detected only by instruments riding outside it. They are radiated under intense magnetic conditions, from gravitational forces, or in explosive environments. Thus, X-ray astronomers tend to observe those parts of the universe where the most violent events occur: exploding stars known as novas and supernovas, material near the event horizons of black holes, and supermassive black holes in the centers of active galaxies, clusters of galaxies, and extremely distant but powerful quasars. "It's a universe that's very different than what was imagined," says Riccardo Giacconi, who first suggested a Chandra-size orbiting X-ray telescope in the early 1960s. Giacconi is today an astrophysicist at Johns Hopkins University and president of Associated Universities Inc., which manages the multi-facility National Radio Astronomy Observatory. "Objects may be faint and far away, but [with Chandra] it's not a blur or a fog anymore."

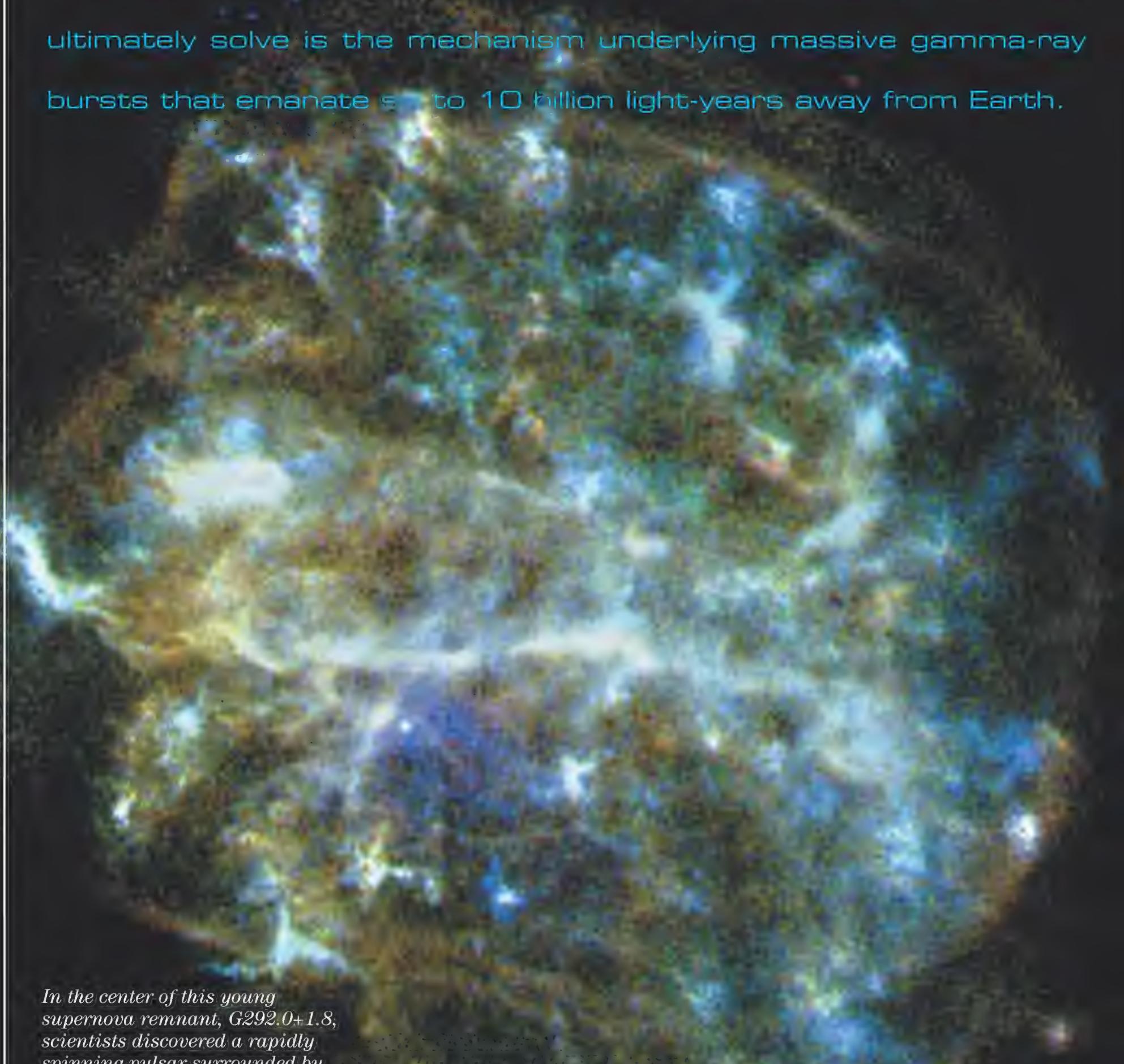
Chandra, the product of a collaboration between NASA, the Harvard-Smithsonian Astrophysical Observatory, MIT, Pennsylvania State University, the aerospace company TRW, and a number of other academic, industrial, and commercial partners, has already been used to make many advances, including confirmation that widespread X-rays detected across the entire sky emanate from the collective emissions of single sources like the energetic, black-hole-fueled cores of galaxies, as well as other active galactic regions, such as stellar nurseries in star clusters. It has also given scientists increasingly detailed views of the environments of black holes; enabled the identification of early stages of star formation; and provided the composition of the extremely hot gases expelled during supernova explosions and from

Though only a small range of the electromagnetic spectrum is visible to human eyes, astronomical objects emit energy in all wavelengths. The energy waves at the lower end of the spectrum—radio, microwave, and infrared—penetrate the atmosphere and thus can be detected by instruments on Earth. Energy at the higher range—ultraviolet, X-ray, and gamma ray—is absorbed by the atmosphere and can be studied only by spacecraft, like the Compton Gamma Ray Observatory, which from 1991 to 2000 detected gamma rays from pulsars, supernova explosions, and black holes.



One key mystery that analysis of Chandra's observations may ultimately solve is the mechanism underlying massive gamma-ray bursts that emanate from 10 billion light-years away from Earth.

CHANDRA/MCGILL



In the center of this young supernova remnant, G292.0+1.8, scientists discovered a rapidly spinning pulsar surrounded by outflowing material. Supernovas are among the primary sources of the heavy elements necessary to form planets and life-forms, and linking the pulsar to the supernova remnants helps scientists determine what types of stars generate such events.

NASA/CXC/RUTGERS/J.HUGHES ET AL



NASA/CXC

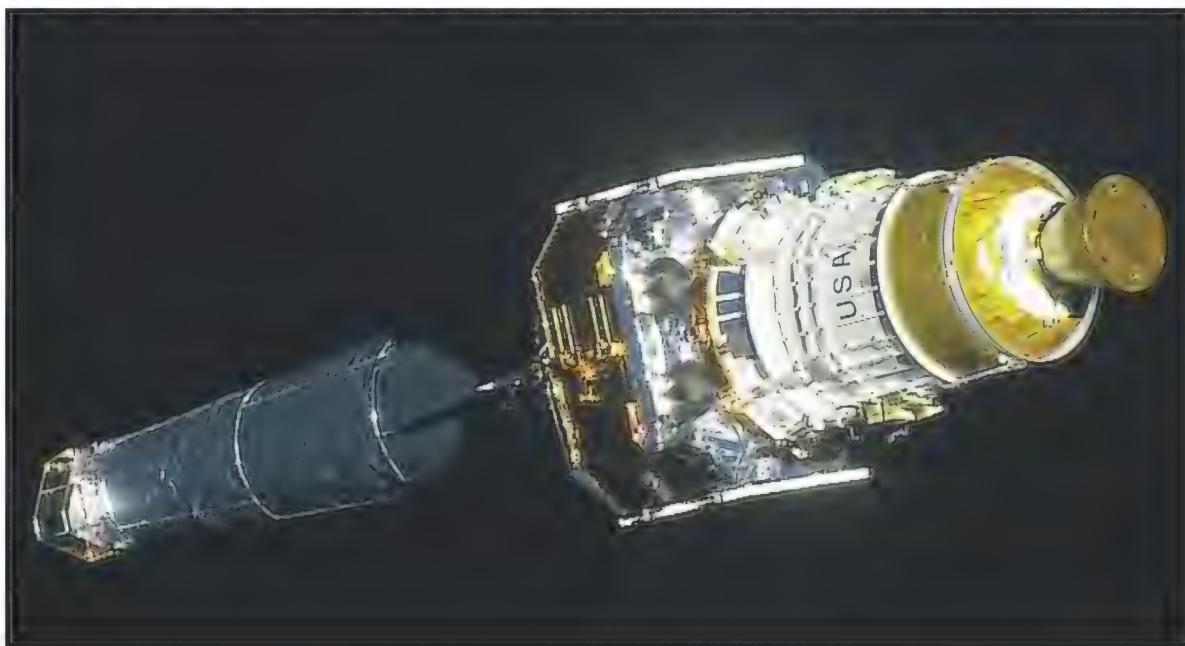
Diffraction gratings in Chandra's cylindrical mirror assembly split X-ray light into its wavelength components for spectral analysis.

the outer layers of stellar atmospheres.

Chandra's journey into space began in 1976, when Harvey Tananbaum, now director of the Chandra X-Ray Center, Giacconi, and seven colleagues submitted a proposal to NASA to build a space observatory capable of collecting and analyzing X-ray emissions from distant sources. Given a budget of \$2 billion (slimmed down from \$6 billion), with annual operating costs of \$50 to \$60 million, the researchers created an 11,000-pound spacecraft some 46 feet long and, including its solar panels, 65 feet wide. Because Chandra is designed to receive and analyze astronomical X-rays, its interior differs from that of an optical telescope. If X-rays were to hit a mirror head on, they would pass straight through. So Chandra's are cylindrical, angled so that X-rays graze off, are captured, and then are funneled to the observatory's instruments for processing.

One key mystery that analysis of the resulting images may ultimately reveal is the mechanism underlying massive gamma-ray bursts that emanate six to ten billion light-years away from Earth. The orbiting Compton Gamma Ray Observatory studied the phenomena, but scientists are still puzzling over them and hope that examining the bursts in X-ray wavelengths will offer additional insight. Could these occurrences represent two neutron stars colliding and coalescing? Perhaps they're *super-super-*

Soon after deployment from the space shuttle Columbia, Chandra's inertial upper stage rocket fired to place the telescope into orbit.



NASA

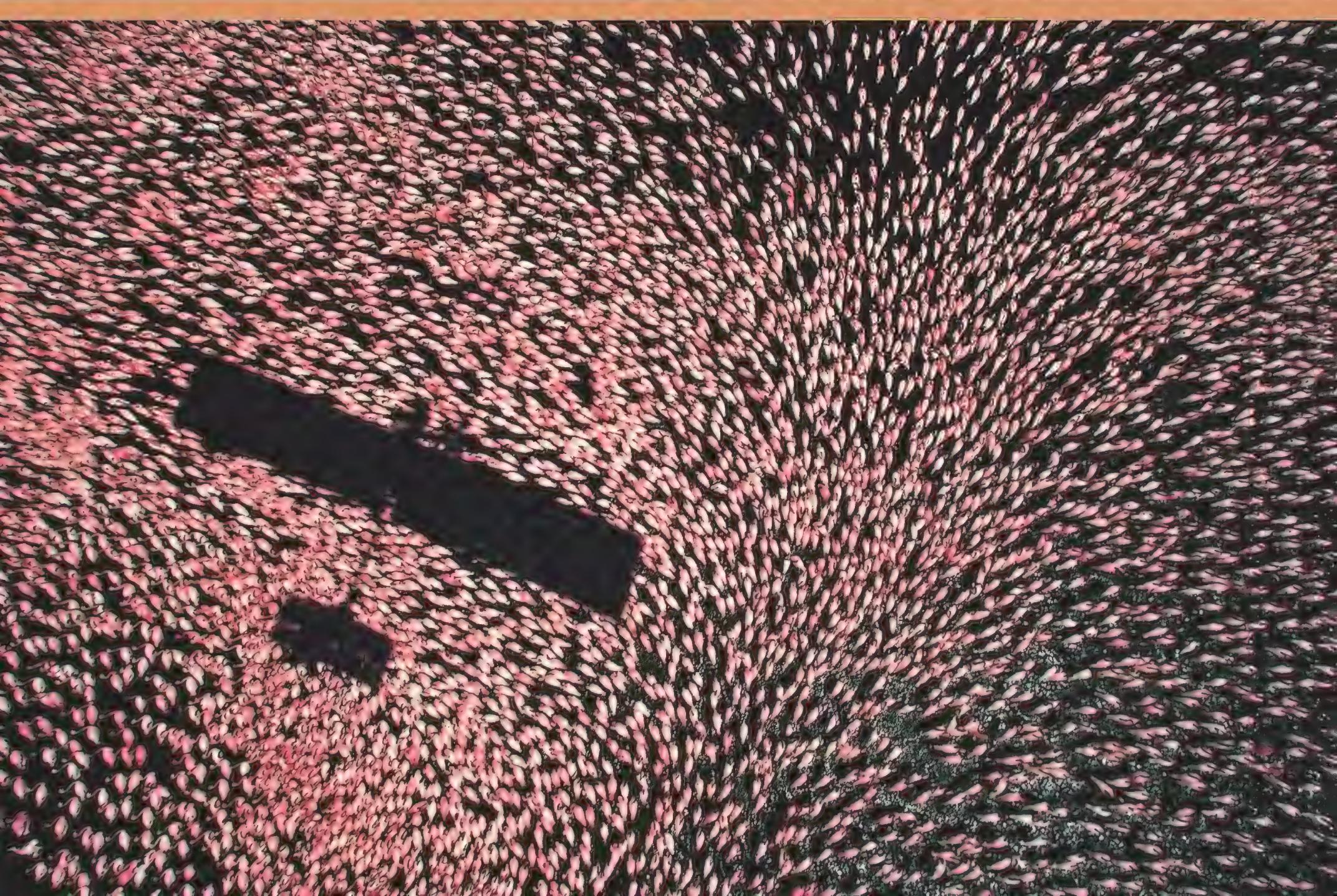
pernovas—"hypernovas," as some have called them, the result of the detonation in the early universe of unstable, ultramassive stars 500 to 1,000 times larger than our sun. Or maybe they're an entirely different class of objects to which a name may some day be attached.

No doubt, say scientists, there are other astronomical conundrums that should yield in time to Chandra's observations. "Astronomy involves a lot of different types of physics and chemistry, but you can't just go into the laboratory to validate your theory," says Leon Van Speybroeck, a contributor to the original 1976 study proposing Chandra and today a telescope scientist with the Harvard-Smithsonian Astrophysical Observatory. "Understanding evolves over time. Someone can't do a single experiment and suddenly settle all questions."

Success has bred huge amounts of data, which is stored in two archives in Cambridge and one just south of Boston, where tape backups are transferred and placed in a guarded vault. Each shift, Chandra generates slightly more than 112 megabytes of data: that's 123 gigabytes per year. Astrophysicists are only now beginning to mine that enormous collection, a task that likely will take years. Although Chandra's operational life is officially five years, most of those affiliated with the project believe its instruments could last for 15.

Many questions and answers are likely to be forthcoming as researchers schedule approximately 800 observing sessions each year. Objects under scrutiny will range from stars to gas clouds to nebulae in the Milky Way and beyond, as well as neighboring and distant galaxies. Observers want to answer basic questions: How do celestial objects form, mature, and perish? What is their nature? How do they behave? What in their basic form and function reveals the inner workings of the universe?

In the end, Chandra's deep view of the universe is no arcane scientific exercise but an exploration that brings a practical understanding home to Earthly doorsteps. Since its formation, the planet has been bombarded by extraterrestrial material. Among the arrivals have been the very elements today found in the crust and mantle, including those we rely on every day. According to Jeffrey Linsky, an astrophysicist at the University of Colorado who has used the telescope, "Your computer wouldn't work without supernovas. There's where the silicon comes from," he says. "The iron in our blood is from a supernova." Indeed, humankind owes its very existence to stellar eruptions that give off material that drifts through the void, enriching the stellar medium and seeding planets, perhaps even life itself.





SIGHTINGS

French photographer Yann Arthus-Bertrand has been recording the state of the planet through aerial photographs since 1990. He spent 3,000 hours photographing 85 countries from helicopters and airplanes. The result is *Earth From Above* (Abrams, NY, 2001), a collection of images that Arthus-Bertrand hopes will "bring about a sense of awareness, a true reflection of the Earth, so that all citizens mobilize and participate in preserving the planet." Photographs from the book, clockwise from above, are:

Cotton fabrics drying in the sun in Jaipur, Rajasthan, India 26°55' N, 75°49' W

The region has been famous for cen-

turies for its handicrafts of dyeing and printing on cotton and silk, practiced by the Chhipa community, though traditional techniques using natural pigments are gradually being abandoned in favor of chemical dyes.

Rose-colored flamingos on Lake Nakuru, Kenya 0°17' S, 36°04' E

The 24-square-mile lake covers one-third of a national park that is home to 370 species of birds. The alkali lake has a high content of sodium carbonate. The briny waters encourage the proliferation of blue-green algae that form the basis of the flamingos' diet. Chemicals used on bordering farmlands and wastewater from the nearby city of Nakuru have polluted the

lake's waters, endangering the wildlife.

Caravan of dromedaries in the vicinity of Nouakchott, Mauritania

18°09' N, 15°29' W

A true "desert ship," the camel actually consumes only 22 to 44 pounds of plants per day and can go without water during the three-month cool season. On the other hand, it can last only a few days without drinking in the summer. In Mauritania, the Moors raise dromedaries for their milk and meat, as well as for their hides and wool. By the end of the 1990s, the dromedary population in this country was estimated to be only one million.

For more information about Yann Arthus-Bertrand, visit the Web at www.yannarthusbertrand.com.

Downing the Avenger

The \$5 Billion Misunderstanding: The Collapse of the Navy's A-12 Stealth Bomber Program

by James P. Stevenson. Naval Institute Press, 2001. 483 pp., \$45 (hardbound).

With service entry initially scheduled for 1995, the delta-wing A-12 Avenger II was to be the Navy's deep-strike stealth replacement for the aging A-6 Intruder. Plans for the stealth bomber showed a pure flying triangle spanning 70 feet, with no traditional vertical, and an elongated Plexiglas blister stretched, cocoon-like, back from the apex to enclose two crew members. With four internal weapons bays, it was initially designed for a 486-mile strike radius at a top speed of 620 mph.

But it never flew. After seven years of research and development and an expenditure of \$5 billion, then-Secretary of Defense Richard Cheney ordered the floundering program canceled in January 1991, triggering the review of 59 million pages of documents and 10 years of lawsuits.

In *The \$5 Billion Misunderstanding*, James P. Stevenson presents a complex and chilling tale of noncommunication, mismanagement, and deception. I recommend starting with Chapter 12, Stevenson's excellent closing summary, before returning to Chapter 1 to experience this grimly detailed saga.

In November 1984, the Navy signed a contract with General Dynamics and McDonnell Douglas to begin designing the A-12. Problem: The contract was illegal. "Congress had not appropriated money for the project," Stevenson reports, and such appropriations are required for funding, according to the U.S. Constitution. Despite what Stevenson calls Northrop's

U.S. NAVY



"unacceptable and unawardable" competing proposal, the Navy blithely reopened negotiations to provide additional time to submit a "best and really final offer," soon known as "the BARFO." Later, although the Navy had promised the contractors data from the B-2, F-117, and other classified programs, the A-12 design team received no such information from the other programs, even though members repeatedly asked for it.

By October 1989, the first flight was almost two years behind schedule and the demonstration/evaluation phase of the program alone was more than \$1 billion over budget. Tom Hafer, an analyst in the Department of Defense's Office of the Comptroller, told the Navy: "These are the worst cost projections I've ever seen so early in a program. This program is headed for disaster." Yet the very next month, Navy program manager Captain Lawrence G. Elberfeld concluded the critical design review meeting by saying that the program was "on schedule, on cost, and on track."

In this Wonderland, Alice would have marveled at the two contradictory briefings given on January 4, 1991: one to Rear Admiral William Morris suggesting that both the Navy and the Joint Chiefs of Staff found the A-12's status acceptable; the other, by Department of Defense investigation director Russell Rau to defense

department staff members, recommending "that the A-12 FSED [Full Scale Engineering Development] contract be terminated for default" on contractual obligations. Three days later, Cheney canceled the program.

According to this meticulously researched account, few emerged from the ensuing lawsuits and trials with clean hands. Two examples: In late 1989, after viewing an essentially empty McDonnell Douglas production space, Lieutenant General Chuck Pitman of the Marine Corps personally expressed to Navy Secretary Larry Garrett a deep concern about delay in A-12 fleet introduction. Nothing was done. "Garrett has no recollection of this meeting," Stevenson reports, "a memory lapse that Pitman found incredible." Additionally, Stevenson cites recollections by several people that Cheney had attended a number of discussions of the program's massive cost overruns and delays only weeks before reporting to Congress on April 26, 1990, that the program was progressing favorably. "Cheney was either daydreaming during these discussions or Cheney lied," Stevenson writes.

This book should be required reading for all in the Cabinet, the Congress, and the Pentagon.

—Theodore L. Gaillard Jr. is a Philadelphia-based writer specializing in defense issues and military technology.

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Sunburst: The Rise of Japanese Naval Air Power 1909-1941

by Mark R. Peattie. Naval Institute Press, 2001. 392 pp., \$34.95 (hardbound).

Sixty years later, we're still teasing out the truth about Pearl Harbor. With *Sunburst*, Mark Peattie goes beyond the December 7, 1941 attack to show how the very strengths of the Japanese navy led to its decline and fall in the years that followed.

"The transcendent symbol of the amazing qualities and fatal weakness of Japanese naval air power," Peattie points out, was the Mitsubishi A6M Zero fighter. "Dazzling in its quickness, extraordinary in its reach, and possessed of great firepower, its vulnerabilities in design and frailties in construction were ultimately discovered and exploited by its foes." The Zero "embodied the central assumption with which the Imperial Japanese Navy went to war: that speed, maneuverability, and firepower would deliver a slashing stroke at the outset and would bring the giant to his knees before he could assert his massive strength."

Like the nation that built it, the long-range Zero was handicapped by a short-range vision. It could fly and fight over 1,000 miles of ocean, but it couldn't withstand the hammering of .50-caliber bullets. When Americans learned how to bring their guns to bear, the Zero was doomed, along with the pilots who flew it and the nation that had created it.

Peattie makes two points that aren't immediately obvious to the student of the Pacific War. First, he argues that the Pearl Harbor attack actually worked to the American advantage: By destroying

our "battle line," the Japanese forced the United States to rethink its war-fighting doctrine. Submarines and aircraft carriers survived the initial blow, so we put them into the vanguard and developed new ways to use them.

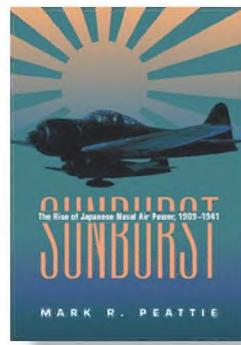
The Japanese, on the other hand, having won the first clash, learned nothing from it. Despite their own success with a carrier task force, they continued to believe in the scenario of a titanic clash between battleships somewhere in the Pacific.

Peattie also disputes the conventional wisdom that Japan lost the war in the June 1942 Battle of Midway. Not until that autumn, he argues, did the tide begin to change.

In the end, Japan was, says Peattie, "outproduced, outorganized, outmanned, and outfought." The navy's own doctrinal failures helped guarantee that outcome: Having staked everything on having nimble aircraft and elite pilots in the opening round, the navy had no counter for the slowly improving U.S. airplanes and pilots ranged against them.

Copious notes—many referring to Japanese-language sources unreachable by most Westerners—add to the value of the book, as do more than 100 pages of appendices: biographical sketches of Japanese navy figures, three-views of aircraft carriers and warplanes, an explanation of the nomenclature, and even an explanation of the *hineri komi*, an improvement on the Immelmann turn that enabled a pilot to turn the tables on a pursuer. All together, this is a must-have for any serious scholar of the Pacific War.

—Daniel Ford's latest book is *The Only War We've Got: Early Days in South Vietnam*.

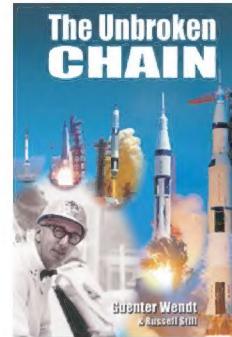


The Unbroken Chain

by Guenter Wendt and Russell Still. Apogee Books, an imprint of Collector's Guide Publishing Ltd., 2001. 216 pp., CD-ROM. \$26.95.

Memoirs of Space Age pioneers are in vogue. In the last few years we've seen books from a host of astronauts, Apollo flight directors, and NASA engineers. *The Unbroken Chain* is another memoir from the heroic era of manned spaceflight, but one written from a unique vantage point. Guenter Wendt was the legendary "pad leader" for all launches of the manned spaceflights, from the first Mercury mission through the last Apollo flights.

As an employee with McDonnell and later North American Rockwell, Wendt was responsible for launch operations and crossed paths with every astronaut and many senior NASA officials. This memoir, co-written with Russell Still, is filled with stories about those interactions—some classic, many never revealed before, a few embarrassing—with astronauts, technicians, engineers, and officials.



Wendt, who emigrated from Germany to the United States in 1949 (though not as a member of Wernher von Braun's German rocket team), describes a relentless pursuit of excellence, safety, and security, both for his team and for the mission under his care. Many astronauts recall how Wendt strapped them into their capsules, shook their hands, offered words of support, and closed the hatch, the last person they saw before their trip into space. In those moments, they were grateful for his abrasive attention to detail and his forceful leadership on the launch pad. They called him "Pad Führer," a term of respect if not always affection.

Wendt's memoir is replete with good-natured stories, and some that are not so good-natured. From Gus Grissom's sexual peccadilloes to Alan Shepard's practical jokes to John Glenn's stuffed-shirt persona, Wendt adds several wild new chapters to the antics of the astronauts.

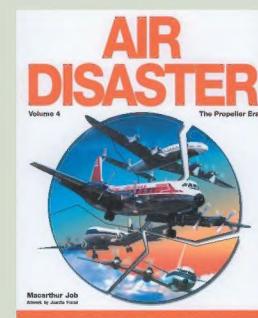
There are some areas where the authors might have broadened our understanding of the complex space launch mission. But even so, this is an interesting, entertaining, and enriching book that will be welcomed by all interested in the development of manned spaceflight in the United States.

—Roger D. Launius is the chief historian at NASA.

CRASH SERIES

Air Disaster, Volume 4: The Propeller Era

by Macarthur Job, Aerospace Publications, 2001. 184 pp., \$21.95. This volume continues the author's excellent series analyzing major air disasters. This time, he examines the propeller airliners of the 1950s and 1960s. As with his studies of more recent events, Job, supported by intricately drawn illustrations, delves deeply into the causes of such events as the collision of a Lockheed Super Constellation and a DC-7 over the Grand Canyon, a string of mysterious Lockheed Electra crashes, and one case in which a Super Constellation ditched in a river within sight of an airport yet was left for over two hours until rescue services finally responded. In each case he describes the experiences of the crews and passengers and the changes in civil aviation procedures that resulted from each crash. Job's previous three volumes focus on jet air disasters, beginning with the de Havilland Comet mysteries of the 1950s.





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CALENDAR

February 17 & March 17

Open Cockpit Sunday. Approximately 12 aircraft open for visitor entry. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (860) 623-3305.

February 21

"Cold War Revisited." Gary Powers Jr. discusses the events that transpired 40 years ago when his father, Francis Gary Powers, was released in a dramatic East-West spy swap. The U-2 he was flying was shot down



*"Well, I started to work on
your oil leak, but one
thing led to another."*

May 1, 1960, over Soviet territory. Virginia Aviation Museum, Richmond International Airport, (804) 236-3622.

February 23

Flying Companion Seminar. Learn about flight instruments, aerodynamics, handling in-flight emergencies, and the requirements for a pilot's license. Sponsored by the Oklahoma Chapter of the Ninety-Nines. Will Rogers Airport, Oklahoma City, OK, (405) 789-0272.

March 13-15

International Women in Aviation Conference. Opryland Hotel, Nashville, TN, (904) 226-7996.

March 21

"Fast FAC—The Stormy Mission." Retired Brigadier General Ken Strafer, U.S. Air Force Special Operation Forces, talks about his combat experiences in Vietnam and the Gulf War. Virginia Aviation Museum, Richmond International Airport, (804) 236-3622.

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, 750 9th Street NW, 7th Floor, Washington, DC 20560. Events will be listed as space allows.

CREDITS

Back in the Saddle. At the end of her Bud Light Jet airshow season, Debbie Gary set out to find the perfect airshow airplane. She thought she had it in a French masterpiece, the CAP-232, but lost the airplane in a recent fire. She now flies a lumbering 1940s Waco biplane and continues her search.

The Fifty-Cent Classic. Tom LeCompte is a freelance writer and pilot who lives in western Massachusetts.

Masters of the V-12. Stephan Wilkinson flies a restored Porsche at very low altitudes near his home in Cornwall, New York.

Erik Hildebrandt photographed the JRS/Metal Masters in his hometown of Minneapolis. He is currently restoring a Cessna L-19 Bird Dog, which he hopes to take to Oshkosh this summer.

Building a Great Air and Space Library. *Air & Space/Smithsonian* photography/illustrations editor Caroline Sheen and National Air and Space Museum staff photographer Eric Long worked together to select, compose, and light the items culled from NASM's collection of artifacts and memorabilia.

Restoration: Delightfully de Havilland. Diane Tedeschi is an associate editor at *Air & Space*.

I Survived the Rotary Rocket. Marti Sarigul-Klijn currently lectures on engineering at the University of California at Davis. He is writing a book on reusable launch vehicle design with his wife, a professor of engineering at Davis.

"This Is Only a Test." Roger A. Mola also writes for *Airshows* and *Aviation International News*. His zeal for tracking and presenting the arcane falls between commendable and obsessive.

David Povilaitis composes collages in a small room in the woods north of San Francisco. Easily distracted by moving shiny things, he is now producing a Wind Art & Technology Festival, to be held this spring.

How Things Work: Shuttle Launch Windows. Eric Adams is an associate editor at *Air & Space*.

The Plane With No Name. William Triplett, a freelance writer living in northern Virginia, has also written about aviation and space for *Newsday*, the *Washington Post*, and *Nature*.

Further reading: *Illusions of Choice: The F-111 and the Problem of Weapons Acquisition Reform*, R.F. Coulam, Princeton University Press, 1977.

X-ray Eyes. James S. Schultz is a science writer who lives and works in Williamsburg, Virginia.

FORECAST



DEAN LA PRAIRIE

Mundelein's Jim Jackson and students in Aviation Technology I.

In the Wings...

Mundelein High

At this suburban Chicago high school, the students take algebra, history, and airplane building.

Journey to an Asteroid

An astronaut explains why the next manned mission should grab a piece of the rock.

ANNUAL AIRSHOW SPECTACULAR:

The Russians Are Coming!

MiGs, Yaks, Sukhois: This season the skies are teeming with Russian airplanes.

Heads Down

How aircraft are modified to fly inverted.

BONUS POSTER

A spotter's guide to the Russian performance aircraft on the airshow circuit.

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CHAD SLATTERY

Tales of the Dragon Rapide

Hillman's Airways, a 1930s British airline, wanted an aircraft capable of carrying six passengers on its London-to-Paris route, and the de Havilland D.H.89 Dragon Rapide was born. For more about de Havilland's little airliner, visit the Web.

While you're there, check out the new Sightings video clip of the Roton Atmospheric Test Vehicle in flight.

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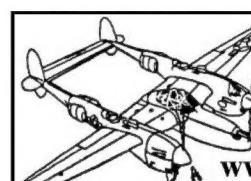
AIR & SPACE Offers Back Issues. Many issues are still available, including February/March 2001, featuring the Soviet program to copy the U.S. B-29, and April/May 2001, featuring the Predator reconnaissance drone and a poster of the F-104 Starfighter.

Send orders and \$5.00 per issue (foreign: \$6.00) to:

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Low and Dark

Air Force Captain Jodi A. Neff of the 3rd Airlift Squadron at Dover Air Force Base in Delaware is the first woman to command one of the world's largest aircraft, the Lockheed C-5 Galaxy, on special operations low-level (SOLL) night missions. This means flying the four-engine mega-transport at altitudes of 500 to 1,000 feet, in marginal weather, with no exterior lighting, and in unfriendly territory to deploy equipment, personnel, or supplies.

Neff began training on the C-5 a scant four years ago after transferring to Dover from a tour of duty in the Midwest, where she flew a much smaller aircraft, the C-21. Taking note of her exceptional skills in the cockpit, her superiors at Dover hand-picked her for the SOLL training program. Today, at age 30, she not only flies the Galaxy, she instructs other pilots, qualifies those upgrading from day to night SOLL operations, and conducts training in C-5 aerial refueling.

Although she majored as an undergraduate in what she calls her "fallback" field, meteorology, she subsequently earned a master's degree in aeronautical science in 1998, the same year she first climbed aboard a C-5.

"You just don't realize how big it is until you strap yourself in," Neff says. "On my first check ride in the C-5 simulator, I landed pretty hard because I was accustomed to being about 10 feet off the ground in other airplanes, whereas in the C-5, I was about 40 feet."

Perceptually, Neff explains, the operating environment becomes



DAN GILL/USAF

particularly tricky when flying at the extremely low altitudes of SOLL missions. Just as objects in car mirrors are closer than they appear, so too, says Neff, is the ground closer than it appears when you are skimming it at three-digit heights. On night SOLL flights, Neff uses night-vision goggles. "Even with little or no moonlight, I can see for miles," she says. "Strangely enough, the hardest part of my job is on the ground. When you are taxiing something as big and heavy as the C-5, you have to think ahead all the time."

With the C-5, Neff has delivered over 200,000 pounds of equipment to U.S. and allied forces in Kuwait, flown three munitions-transport missions in Kosovo, conducted humanitarian flights during civil unrest in East Timor, and helped evacuate typhoon victims in Korea.

Last year, the National Aeronautic Association presented Neff with its Katherine and Marjorie Stinson Award for Achievement in recognition of her singular success on the Galaxy flight deck after only seven years in the military. The NAA said Neff's accomplishments in the SOLL arena recall the pioneering spirit of the Stinson sisters. One of Katherine Stinson's tricks in the early 1900s was to perform night maneuvers with flares on her aircraft to trace her path against the dark sky.

—*Stuart Nixon*

Moments & Milestones is produced in association with the National Aeronautic Association. Visit the NAA Web site at www.naa-usa.org or call (703) 527-0226.

LOGBOOK

Events

The National Aeronautic Association will hold its annual **Spring Awards Ceremony** at the National Air and Space Museum in Washington, D.C., on Thursday, April 4, 2002. This year's event will be co-hosted by the Civil Air Patrol.

The 2001 **Robert J. Collier Trophy** will be presented at a dinner held by the National Aviation Club on May 29, 2002, at the Crystal Gateway Marriott in Arlington, Virginia. The Robert J. Collier Trophy is awarded annually "...for the greatest achievement in aeronautics or astronautics in America, with respect to improving the performance, efficiency, or safety of air or space vehicles, the value of which has been thoroughly demonstrated by actual use during the preceding year."

Nominations

Nominations for the **Katharine Wright Memorial Award** will be accepted until March 31, 2002. The annual award is given to a woman who has "provided encouragement, support and inspiration to her husband and thus was instrumental in his success; or made a personal contribution to the advancement of the art, sport and science of aviation and space flight over an extended period of time."

Nominations for the **Harmon Aeronaut (Ballooning) Trophy** will be accepted from March 1, 2002, to May 30, 2002. The trophy is awarded each year "for the most outstanding international achievement in the art and/or science of aeronautics (ballooning) for the preceding year, with the art of flying receiving first consideration."

Nominations for the **Cliff Henderson Award for Achievement** will be accepted until April 30, 2002. It is awarded yearly "to a living individual or group whose vision, leadership, or skill has made a significant and lasting contribution to the promotion and advancement of aviation or space activity."